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N INVESTIGATION OF THE EFFECTIVENESS OF XISTING BRIDGE DESIGN METHODOLOGY IN ROVIDING ADEQUATE STRUCTURAL RESISTANCE O SEISMIC DISTURBANCES. Phase III: Analytical Investigations of Seismic Response of Short, Single, or Multiple-Span Highway Bridges.

M. Chen and J. Penzien

October 1974
Final Report

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Offices of Research & Development
Washington, D.C. 20590

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16. Abstract
This report is the third in a series to result from the study, "An Investigation of the Effectiveness of Existing Bridge Design Methodology in Providing Adequate Structural Resistance to Seismic Disturbances," sponsored by the U. S. Department of Transportation, Federal Highway Administration. Descriptions are given to the analytical investigations of the seismic response of short, single or multiple-span highway bridges of the type where soil-structure interaction effects are important.

Six different mathematical model elements are incorporated into the computer program which possess the capability of performing linear or non-linear analyses. Finite element modeling is used for the backfill soils. Bridge deck, piers, and abutments are modeled using prismatic beam elements. A frictional element is used to model the discontinuous behavior at the interface of backfill soils and abutments. Discontinuous type expansion joint elements are also included. Linear spring elements provide flexibility at the vertical soil boundaries. The soil foundation flexibilities under columns are established using elastic half-space theory. In the non-linear mathematical model the effects of separation and impact at the interface between abutments and backfills, the yielding at concrete columns and backfill soils and slippage at the expansion joints are taken into consideration.

Parameter studies are first carried out considering a rigid wall backfill soil system. A short, stiff, three-span bridge is then investigated with full soil-structure interaction effects included. Finally, based on the analytical results, a general conclusion regarding the analyses capability is deduced.

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Memorandum

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

FEB 18 1975

TO : Individual Researchers

DATE:

In reply refer to: HRS-11

FROM : James D. Cooper, Project Manager, FCP Project 5A, Improved Protection Against Natural Hazards of Earthquake and Wind

SUBJECT: Transmittal of Research Report No. FHWA-RD-75-10
"Effectiveness of Existing Bridge Designs in Resisting Earthquakes, Phase III: Short, Single or Multiple-Span Highway Bridges"

Distributed with this memorandum is the subject report intended primarily for research audiences. This report will be of interest to structural researchers concerned with earthquake resistant highway bridges.

This recently issued report is the third in a series to result from research being conducted at the University of California, Berkeley, for the Federal Highway Administration. Analytical investigations of the seismic response of short, single or multiple-span highway bridge structures of the type which suffered heavy damage during the San Fernando earthquake of February 9, 1971, are described in the report.

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Attachment

PREFACE

The investigation with interpretation as described in this report was sponsored by the U. S. Department of Transportation, Federal Highway Administration, under Contract No. DOT-FH-11-7798 covering the period July 1, 1971 through September 30, 1974.

The general investigation called for in this contract is under the supervision and technical responsibility of Professors R. W. Clough, W. G. Godden, and J. Penzien. Professor Penzien acts as principal investigator.

ACKNOWLEDGEMENT

The authors wish to express their sincere appreciation to the California State Division of Highways, Department of Public Works, for providing the engineering data of the bridge structures studied in this investigation.

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I INTRODUCTION

A. STATEMENT OF PROBLEM

The seismic response of short, single or multiple span, highway bridges are greatly affected by the phenomenon of soil-structure interaction. The dynamic forces exerted by backfills on the abutments often add significantly to the maximum seismic forces developed in the overall structural system. Also, bridges of this type usually have relatively short and stiff columns which interact strongly with their supporting foundations. Neglecting these interaction effects can lead to large errors in predicting design loads. It is therefore the objective of this investigation to establish appropriate mathematical models which will yield realistic seismic response for certain soil-structure systems of this type. Further, computer programs are written to carry out time-history dynamic analyses as an aid to the design process.

B. REVIEW OF PERTINENT RESEARCH INVESTIGATIONS

Numerous analytical investigations have been carried out in the past to determine dynamic earth pressures acting on retaining walls. One of the earliest was carried out by Okabe and later a similar study was reported by Mononobe and Matsuo [80, 74]*. In each of these investigations an equivalent static earth pressure was determined as a function of acceleration with its resultant acting on the wall at a

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*Numbers in square brackets refer to Bibliography numbers.

position corresponding to that of static fluid pressure, i.e. at a height one-third the distance from the base. Much later, Valera used the finite element method to predict the intensities of seismic earth pressures acting on rigid walls [106]. In this investigation, nonlinear soil behavior was considered. Seed and Whitman summarized 31 investigations carried out from 1926 to 1969 and made valuable suggestions for their application to design [97]. Later, Wood derived analytical expressions for earth pressures acting against rigid and rotating walls using linear soil properties [117]. All of these investigations were concerned with intensities of dynamic pressures but in each case they assumed the pressures to act independently of the dynamic response of the wall itself.

In recent years, the influence of soil conditions on the seismic response of structural systems has received considerable attention. Seed recently published a report covering two main aspects of this problem: (1) changes in seismic ground motions adjacent to buildings as a result of physical interaction effects, and (2) changes in seismic response of buildings as a result of the changes in ground motions due to different soil deposits. This investigation did not, however, include full dynamic soil-structure interaction effects for structures other than buildings [98].

Few analytical investigations have been reported in which dynamic soil-bridge interaction effects were treated rigorously. One such study was reported by Penzien in 1970 [82]. In this particular investigation, the soil foundation was represented by a series of lumped masses interconnected by bilinear hysteretic shear springs having properties which varied with soil depth and also interconnected with

viscous linear dashpots. The bridge deck, supporting piers, and pile foundations were also modelled as lumped mass systems. The three dimensional effects of the foundation soils were determined using the Mindlin Theory of the elastic half-space. Equations of motion were developed which considered all dynamic interaction effects. Recently, Tseng and Penzien reported an investigation on the seismic response of long multiple span bridges in which the mathematical modelling included soil-structure interaction effects at the bases of columns; however, due to the long structural types considered, soil-abutment interaction effects were neglected [105].

As far as experimental results are concerned, most investigations have been carried out on simple wall-soil systems. Important contributions have been made by Matsuo, Ishii and Arai and Tsuchida, Matsuo and Ohara, Tschebotanoff, Ohara, and Niwa [68, 52, 69, 104, 79, 78].

Shepherd and Charleson, and Shepherd and Sidwell have conducted field experiments on an existing bridge in the small loading range [100, 101]. Their results show that the soil around the bridge displayed high energy absorption qualities, i.e. provided considerable damping to the overall soil-structure system. Broms and Ingelson have also conducted field experiments to determine the static earth pressures acting on abutment walls [11].

C. REVIEW OF DAMAGES CAUSED BY EARTHQUAKES

Iwasaki, Penzien, and Clough prepared an extensive summary of the damages caused to bridges during earthquakes for the period 1923 to 1971 [53]. Jennings and Wood, and Lew, Legendecker, and Dikkers have

reported on the damages to bridges during the San Fernando earthquake of February 9, 1971 [59, 65]. Duke and Leeds reported similar damages caused by the Chilean earthquake of 1960, while Rose, Seed, and Migliaccio reported on the Alaskan earthquake of 1964 [29, 92]. As indicated in these reports, short bridges have suffered damages ranging from column failures to cracking, tilting, and even overturning of piers, abutments, and wing walls. Clearly, this evidence shows that large dynamic forces are induced in the overall structural system by backfill earth pressures.

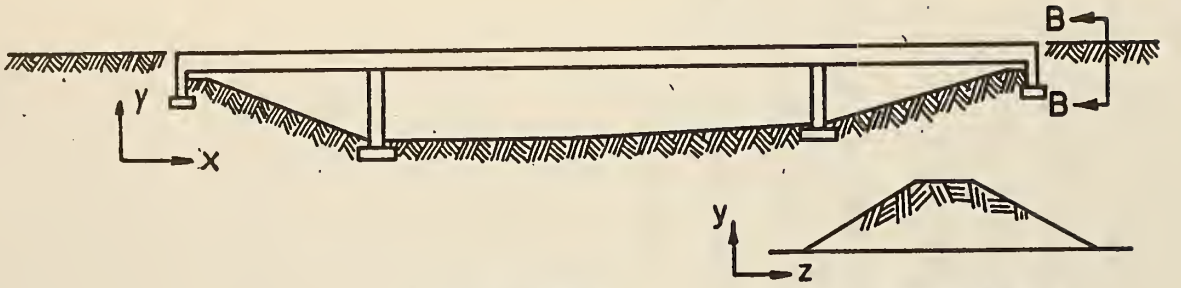
D. SCOPE OF PRESENT INVESTIGATION

The present investigation is a study of the seismic response of short, single or multiple span, highway bridges having narrow abutment backfills as shown in Fig. 1.

Since the earth pressures acting against the abutments can greatly affect the seismic response of the bridge, the mathematical modelling includes a two-dimensional soil element representation of the abutment backfills. This representation accounts for nonlinear soil properties and allows different vertical boundaries to be present as shown in Figs. 1D, 1E and 1F. The bridge deck, piers (or columns), and abutments are modelled using prismatic beam elements which may be permitted to have hysteretic yielding properties. A frictional element is used to model the nonlinear, discontinuous behavior at the interfaces of backfill soils and abutments and nonlinear, discontinuous type of expansion joint element is included. The soil foundation flexibilities under the columns are represented by equivalent columns. The mathematical model

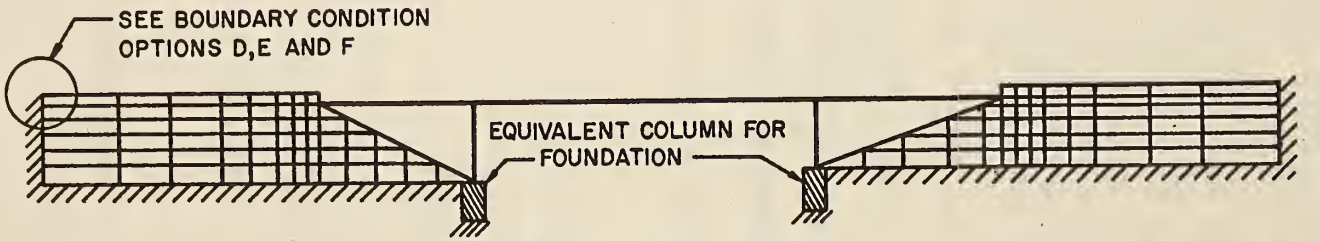
of the overall soil-structure system permits the study of interaction effects and yields the distribution of forces throughout the system.

Chapter II of this report describes the different elements used in the mathematical modelling and presents the derivations of elastic stiffnesses used for these elements. Chapter III discusses soil material properties used in the modelling with particular emphasis on nonlinear properties. Chapter IV develops the stiffnesses of nonlinear elements with emphasis on the derivation of the elasto-plastic force-displacement relations for the soil finite elements and the bridge column elements. Chapter V presents the numerical techniques used in the time-history dynamic analysis while Chapter VI presents the results of parameter studies. Chapter VII presents certain conclusions and recommendations. Finally, listings of the computer program are presented in Appendix A.

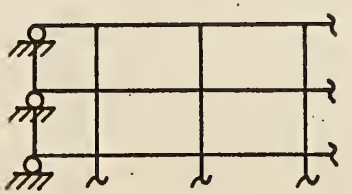


A. ELEVATION

B. SECTION B-B



C. ANALYTICAL MODEL



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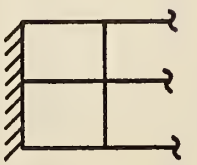

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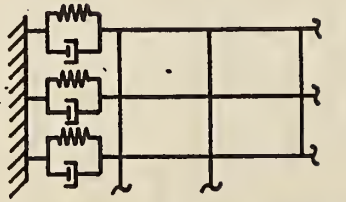


F. SPRING AND DASHPOT

FIG. 1 BRIDGE STRUCTURE AND ANALYTICAL MODEL

II ELASTIC STIFFNESSES OF MODEL ELEMENTS

Six basic elements are used in the mathematical modelling of the bridge-soil system (1) soil finite element of a continuum, (2) soil boundary element, (3) frictional element at interface of soil and abutment wall, (4) prismatic beam element, (5) expansion joint element, and (6) equivalent column of foundation. It is the purpose of this chapter to describe these elements and to derive their elastic stiffnesses.

A. SOIL FINITE ELEMENT OF A CONTINUUM

The bridge-soil system shown in Fig. 1 is subjected to earthquake motions in the vertical direction and in one horizontal direction coinciding with the longitudinal axis of the bridge. Because of the conditions of symmetry, it is assumed that the soils adjacent to the abutments respond to these motions in a two-dimensional manner. This assumption allows these soils to be modelled using two-dimensional finite elements of a continuum interconnected at their nodal points. Material properties are defined individually for each element which may have an arbitrary quadrilateral or triangular shape.

The quadrilateral element used is the isoparametric element for which the geometry and displacements are described in terms of the same parameters of similar order. Using the natural coordinate system and interpolation displacement models, the isoparametric formulation has several advantages over the generalized coordinate method [25]. First,

the nodal displacements provide a more direct visualization of actual structural deformations than do the generalized displacements. Second, it is computationally more efficient since no transformation from one coordinate system to another is required. Finally, the local coordinate system of the isoparametric approach coincides with the global coordinate system; thus, eliminating the need for transformation of loads and stiffnesses from one coordinate frame to the other.

The following derivation of the stiffness matrix for the two-dimensional quadrilateral isoparametric element is similar to that found in certain textbooks [25, 34, 118].

1. Coordinate System - The global Cartesian coordinates (x,y) and the local (or natural) coordinates (s,t) as shown in Fig. 2 are related through an interpolation function h_i by the relations

$$x = \sum_{i=1}^{4} h_i x_i$$
$$y = \sum_{i=1}^{4} h_i y_i \qquad (1)$$

where

$$h_1 = \tfrac{1}{4}(1-s)(1-t)$$
$$h_2 = \tfrac{1}{4}(1+s)(1-t)$$
$$h_3 = \tfrac{1}{4}(1+s)(1+t) \qquad (2)$$
$$h_4 = \tfrac{1}{4}(1-s)(1+t)$$

2. Strain-Displacement Equations - The displacements are approximated using the same interpolation function which can provide for both

flexible and rigid body modes. In this case, one can state

$$u_x(s,t) = \sum_{i=1}^{4} h_i u_{x_i}$$
$$u_y(s,t) = \sum_{i=1}^{4} h_i u_{y_i} \tag{3}$$

The two-dimensional strains are obtained by taking derivations of the displacements with respect to x and y in the following manner:

$$\underline{\varepsilon} = \begin{Bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{xy} \end{Bmatrix} = \begin{Bmatrix} \frac{\partial u_x}{\partial x} \\ \frac{\partial u_y}{\partial y} \\ \frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x} \end{Bmatrix} = \begin{Bmatrix} \sum_{i=1}^{4} \frac{\partial h_i}{\partial x} u_{x_i} \\ \sum_{i=1}^{4} \frac{\partial h_i}{\partial y} u_{y_i} \\ \sum_{i=1}^{4} \left(\frac{\partial h_i}{\partial y} u_{x_i} + \frac{\partial h_i}{\partial x} u_{y_i} \right) \end{Bmatrix} \tag{4}$$

Since functions h_i (i=1,2,3,4) are expressed in terms of s and t, the chain rule of derivations can be applied using the equations

$$\frac{\partial h_i}{\partial x} = \frac{\partial h_i}{\partial s}\frac{\partial s}{\partial x} + \frac{\partial h_i}{\partial t}\frac{\partial t}{\partial x}$$
$$\frac{\partial h_i}{\partial y} = \frac{\partial h_i}{\partial s}\frac{\partial s}{\partial y} + \frac{\partial h_i}{\partial t}\frac{\partial t}{\partial y} \tag{5}$$

The chain rule is

$$\begin{Bmatrix} \frac{\partial(\ )}{\partial s} \\ \frac{\partial(\ )}{\partial t} \end{Bmatrix} = \begin{bmatrix} \frac{\partial x}{\partial s} & \frac{\partial y}{\partial s} \\ \frac{\partial x}{\partial t} & \frac{\partial y}{\partial t} \end{bmatrix} \begin{Bmatrix} \frac{\partial(\ )}{\partial x} \\ \frac{\partial(\ )}{\partial y} \end{Bmatrix} \tag{6}$$

which in its inverted form becomes

$$\begin{Bmatrix} \frac{\partial(\ )}{\partial x} \\ \\ \frac{\partial(\ )}{\partial y} \end{Bmatrix} = \frac{1}{J} \begin{bmatrix} \frac{\partial y}{\partial t} & -\frac{\partial y}{\partial s} \\ \\ -\frac{\partial x}{\partial t} & \frac{\partial x}{\partial s} \end{bmatrix} \begin{Bmatrix} \frac{\partial(\ )}{\partial s} \\ \\ \frac{\partial(\ )}{\partial t} \end{Bmatrix} \tag{7}$$

where the Jacobian J is defined by

$$J = \frac{\partial x}{\partial s}\frac{\partial y}{\partial t} - \frac{\partial x}{\partial t}\frac{\partial y}{\partial s} \tag{8}$$

Thus, the required derivatives are given by

$$\begin{bmatrix} \frac{\partial s}{\partial x} & \frac{\partial t}{\partial x} \\ \\ \frac{\partial s}{\partial y} & \frac{\partial t}{\partial y} \end{bmatrix} = \frac{1}{J} \begin{bmatrix} \frac{\partial y}{\partial t} & -\frac{\partial y}{\partial s} \\ \\ -\frac{\partial x}{\partial t} & \frac{\partial x}{\partial s} \end{bmatrix} \tag{9}$$

Taking derivatives of Eqs. (1), one can write

$$\begin{aligned} \frac{\partial x}{\partial s} &= \sum_{i=1}^{4} \frac{\partial h_i}{\partial s} x_i \\ \frac{\partial x}{\partial t} &= \sum_{i=1}^{4} \frac{\partial h_i}{\partial t} x_i \\ \frac{\partial y}{\partial s} &= \sum_{i=1}^{4} \frac{\partial h_i}{\partial s} y_i \\ \frac{\partial y}{\partial t} &= \sum_{i=1}^{4} \frac{\partial h_i}{\partial t} y_i \end{aligned} \tag{10}$$

Making use of Eqs. (2) and (10), the Jacobian, as defined by Eq. (8) becomes

$$J = \frac{1}{8}[s(x_3 - x_4)(y_1 - y_2) - (x_1 - x_2)(y_3 - y_4)$$
$$+ t(x_2 - x_3)(y_1 - y_4) - (x_1 - x_4)(y_2 - y_3) \quad (11)$$
$$+ (x_1 - x_3)(y_2 - y_4) - (x_2 - x_4)(y_1 - y_3)]$$

and the strain vector defined by Eq. (4) becomes

$$\underline{\varepsilon} = \begin{bmatrix} \frac{\partial h_1}{\partial x} & 0 & \frac{\partial h_2}{\partial x} & 0 & \frac{\partial h_3}{\partial x} & 0 & \frac{\partial h_4}{\partial x} & 0 \\ 0 & \frac{\partial h_1}{\partial y} & 0 & \frac{\partial h_2}{\partial y} & 0 & \frac{\partial h_3}{\partial y} & 0 & \frac{\partial h_4}{\partial y} \\ \frac{\partial h_1}{\partial y} & \frac{\partial h_1}{\partial x} & \frac{\partial h_2}{\partial y} & \frac{\partial h_2}{\partial x} & \frac{\partial h_3}{\partial y} & \frac{\partial h_3}{\partial x} & \frac{\partial h_4}{\partial y} & \frac{\partial h_4}{\partial x} \end{bmatrix} \begin{Bmatrix} u_{1x} \\ u_{1y} \\ u_{2x} \\ u_{2y} \\ u_{3x} \\ u_{3y} \\ u_{4x} \\ u_{4y} \end{Bmatrix} \quad (12)$$

or in compact form may be expressed as

$$\underline{\varepsilon} = \underline{B}\,\underline{u} \quad (13)$$

The derivatives in the coefficient matrix of Eq. (12) can now be expressed in their final maniputable form

$$\frac{\partial h_1}{\partial x} = \frac{1}{16J}[y_2(h_1 + h_2) + y_3(h_4 - h_2) - y_4(h_1 + h_4)]$$
$$\frac{\partial h_2}{\partial x} = \frac{1}{16J}[-y_1(h_1 + h_2) + y_3(h_2 + h_3) + y_4(h_1 - h_3)]$$
$$\frac{\partial h_3}{\partial x} = \frac{1}{16J}[y_1(h_2 - h_4) - y_2(h_2 + h_3) + y_4(h_3 + h_4)]$$
$$\frac{\partial h_4}{\partial x} = \frac{1}{16J}[y_1(h_1 + h_4) + y_2(h_3 - h_1) - y_3(h_4 + h_3)]$$
$$\frac{\partial h_1}{\partial y} = \frac{1}{16J}[-x_2(h_1 + h_2) + x_3(h_2 - h_4) + x_4(h_1 + h_4)]$$

$$\frac{\partial h_2}{\partial y} = \frac{1}{16J}\left[x_1(h_1 + h_2) - x_3(h_2 + h_3) + x_4(h_3 - h_1)\right]$$

$$\frac{\partial h_3}{\partial y} = \frac{1}{16J}\left[x_1(h_4 - h_2) + x_2(h_2 + h_3) - x_4(h_3 + h_4)\right]$$

$$\frac{\partial h_4}{\partial y} = \frac{1}{16J}\left[-x_1(h_1 + h_4) + x_2(h_1 - h_3) + x_3(h_3 + h_4)\right]$$

(14)

Using standard index notation with i permutating 1 through 4, Eqs. (14) can be written in the two single equations

$$\frac{\partial h_i}{\partial x} = \frac{1}{16J}\left[y_{i+1}(h_i + h_{i+1}) + y_{i+2}(h_{i+3} - h_{i+1}) - y_{i+3}(h_i + h_{i+3})\right]$$

$$\frac{\partial h_i}{\partial y} = \frac{1}{16J}\left[-y_{i+1}(h_i + h_{i+1}) + x_{i+2}(h_{i+1} - h_{i+3}) + x_{i+3}(h_i + h_{i+3})\right]$$

(15)

3. Element Stiffness and Numerical Integration - Considering a thickness ω (normal to the plane of element shown in Fig. 2), the element stiffness matrix can be expressed in the form

$$\underline{K} = \int_{vol} \underline{B}^T \underline{C}\, \underline{B}\, dv = \int_{area} \underline{B}^T \underline{C}\, \underline{B}\, \omega dA \qquad (16)$$

where $\underline{C}$ is the stress-strain matrix with integration being carried out over the entire area of the element. For purposes of numerical integration, Eq. (16) can be written in terms of the s and t coordinates giving

$$\underline{K} = \int_{-1}^{1}\int_{-1}^{1} \underline{B}^T \underline{C}\, \underline{B}\, (\det J)\, \omega ds\, dt \qquad (17)$$

Upon application of standard one-dimensional numerical integration formulas, Eq. (17) becomes

$$\underline{K} = \sum_j \sum_k \omega_j \omega_k \ (\det J)\ \underline{B}^T(s_j, t_k)\ \underline{C}\ \underline{B}\ (s_j, t_k)\omega \qquad (18)$$

in which s_j and t_k are integration points and ω_j and ω_k are the appropriate weighting functions. Using the Gauss-Legendre quadrature formula of degree 2, one obtains

$$\left.\begin{aligned} s_i &= \pm\ 0.577350 \\ t_i &= \pm\ 0.577350 \\ \omega_i &= 1 \end{aligned}\right\} \qquad i = 1,2 \qquad (19)$$

For plane stress, matrix $\underline{C}$ has the form

$$\underline{C} = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} \qquad (20)$$

while for plane strain it becomes

$$\underline{C} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & 0 \\ \nu & 1-\nu & 0 \\ 0 & 0 & \frac{1-2\nu}{2} \end{bmatrix} \qquad (21)$$

where E is Young's Modulus and ν is Poisson's ratio.

As shown above, the final form of the element stiffness matrix is a function of geometry, element thickness, and material properties. The overall stiffness matrix of the entire system is assembled by the direct stiffness method [22]. The band width of this matrix depends upon the system of numbering nodal points. Therefore, the nodal points should be numbered in a manner to minimize computer storage requirement

and operating time.

B. SOIL BOUNDARY ELEMENT

Boundary elements are used in the mathematical model to account for the elastic action which occurs at the vertical boundaries of the soils being considered. The type of element used for this purpose is a simple elastic spring as shown in Fig. 3. This element has a stiffness matrix $\underline{k}$ in the local coordinate system of the form

$$\underline{k} = E \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \tag{22}$$

where E is the equivalent stiffness of the spring, which can be obtained using standard methods [82,89].

C. PRISMATIC BEAM ELEMENT

Prismatic beam elements are used to model the bridge deck, piers, abutment walls and equivalent columns for soil foundations. The derivation of the stiffness matrix for a beam element considering axial, shear, and bending deformations can be found in many textbooks [86]. Therefore, only the main features of this matrix will be presented here.

The force components acting on the beam element are axial forces s_1 and s_4, shearing forces s_2 and s_5, and bending moments s_3 and s_6 as shown in Fig. 4. The positive directions of these force components (s) and their respective displacement components (u') correspond to those shown in the figure. The stiffness matrix for this element in terms of

the local coordinates is given by the standard form

$$\underline{k}_{(6x6)} = \begin{bmatrix} \frac{EA}{\ell} & & & & & \\ 0 & \frac{12EI_z}{\ell^3(1+\phi_y)} & & & \text{SYMMETRICAL} & \\ 0 & \frac{6EI_z}{\ell^2(1+\phi_y)} & \frac{(4+\phi_y)EI_z}{\ell(1+\phi_y)} & & & \\ -\frac{EA}{\ell} & 0 & 0 & \frac{EA}{\ell} & & \\ 0 & \frac{-12EI_z}{\ell^3(1+\phi_y)} & \frac{-6EI_z}{\ell^2(1+\phi_y)} & 0 & \frac{12EI_z}{\ell^3(1+\phi_y)} & \\ 0 & \frac{6EI_z}{\ell^2(1+\phi_y)} & \frac{(2-\phi_y)EI_z}{\ell(1+\phi_y)} & 0 & \frac{-6EI_z}{\ell^2(1+\phi_y)} & \frac{(4+\phi_y)EI_z}{\ell(1+\phi_y)} \end{bmatrix} \tag{23}$$

where

$$\phi_y = \frac{12EI_z}{G\ Asy\ \ell^2} = 24(1+\nu)\frac{A}{Asy}\left(\frac{\gamma_z}{\ell}\right)^2 \tag{24}$$

represents the shear deformation parameter for reinforced concrete elements and where

ℓ = element length

γ_z = radius of gyration about z axis

I_z = Moment of inertia about z axis

A = cross sectional area

Asy = equivalent shear area in y direction

E = modulus of elasticity

G = modulus of elasticity in shear

ν = Poisson's ratio

The matrix equation relating displacements in the local coordinates u' to displacements in the global coordinates $\underline{u}$ is given by

$$\underline{u}' = \underline{\lambda}\,\underline{u} \tag{25}$$

where λ has the two-dimensional form

$$\underline{\lambda} = \begin{bmatrix} D_x/D_\ell & D_y/D_\ell & 0 & 0 & 0 & 0 \\ -D_y/D_\ell & D_x/D_\ell & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & D_x/D_\ell & D_y/D_\ell & 0 \\ 0 & 0 & 0 & -D_y/D_\ell & D_y/D_\ell & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{26}$$

and where

$$\begin{aligned} D_x &= x_j - x_i \\ D_y &= y_j - y_i \\ D_\ell &= \sqrt{D_x^2 + D_y^2} \end{aligned} \tag{27}$$

Thus, the stiffness matrix $\underline{K}$ in global coordinates becomes

$$\underline{K} = \underline{\lambda}^T\,\underline{k}\,\underline{\lambda} \tag{28}$$

as indicated above, the stiffness matrix is linearly proportional to the areas and moments of inertia. Therefore, a unit width analysis can be carried out, if desired, by dividing all areas and moments of

inertia by the width of the bridge deck.

D. FRICTIONAL ELEMENT

A so called frictional element is used to model the frictional action, separation, and impact which take place at the interfaces of soil backfills and abutment walls. This element has the following characteristics (1) the frictional force per unit area is proportional to the normal interface pressure and a coefficient of friction; thus, slippage occurs when the direction angle of the resultant of pressure and friction exceeds the soil angle of friction, (2) impact occurs at the interface upon closure of any gap which may have earlier developed, and (3) no frictional resistance can develop at the interface when wall and soil surfaces have separated. Discontinuous elements similar to this have been developed by Ghaboussi and Wilson, Scholes and Strover, White and Enderly, and Tseng and Penzien [40, 94, 111, 105]; however, the element developed by Goodman and Taylor has been adopted here [41].

This frictional element is a four nodal element as shown in Fig. 5 having length L but with a height equal to zero, i.e. nodal points 1 and 4 coincide as do points 2 and 3. It is shown in a local coordinate system with the origin at the center of the element and the x axis directed along the length of the element.

The relative displacement vector $\underline{u}$ is expressed in terms of the displacement vector $\underline{u}_i$ through the linear interpolation function formula

$$\underline{u} = \begin{Bmatrix} (u_x^{top} - u_x^{bottom}) \\ (u_y^{top} - u_y^{bottom}) \end{Bmatrix}$$

or

$$\underline{u} = \begin{bmatrix} -(1-\frac{2x}{L}) & 0 & -(1+\frac{2x}{L}) & 0 & (1+\frac{2x}{L}) & 0 & (1-\frac{2x}{L}) & 0 \\ 0 & -(1-\frac{2x}{L}) & 0 & -(1+\frac{2x}{L}) & 0 & (1+\frac{2x}{L}) & 0 & (1+\frac{2x}{L}) \end{bmatrix} \begin{Bmatrix} u_{1x} \\ u_{1y} \\ u_{2x} \\ u_{2y} \\ u_{3x} \\ u_{3y} \\ u_{4x} \\ u_{4y} \end{Bmatrix} \tag{29}$$

The material property matrix $\underline{k}$ expressing the stiffness per unit length in the normal and tangential directions is given by

$$\underline{k} = \begin{bmatrix} k_s & 0 \\ 0 & k_n \end{bmatrix} \tag{30}$$

Upon applying the variational principle of solid mechanics, the elastic stiffness matrix in the local coordinate system becomes

$$\underline{K} = \frac{l}{6} \begin{bmatrix} 2k_s & 0 & 1k_s & 0 & -1k_s & 0 & -2k_s & 0 \\ 0 & 2k_n & 0 & 1k_n & 0 & -1k_n & 0 & -2k_n \\ 1k_s & 0 & 2k_s & 0 & -2k_s & 0 & -1k_s & 0 \\ 0 & 1k_n & 0 & 2k_n & 0 & -2k_n & 0 & -1k_n \\ -1k_s & 0 & -2k_s & 0 & 2k_s & 0 & 1k_s & 0 \\ 0 & -1k_n & 0 & -2k_n & 0 & 2k_n & 0 & 1k_n \\ -2k_s & 0 & -1k_s & 0 & 1k_s & 0 & 2k_s & 0 \\ 0 & -2k_n & 0 & -1k_n & 0 & 1k_n & 0 & 2k_n \end{bmatrix} \tag{31}$$

E. EXPANSION JOINT ELEMENT

An expansion joint may be present between the bridge deck and an abutment as shown in Fig. 6. This joint can develop horizontal frictional forces which should be modelled properly. For this purpose, the frictional element previously described can be adopted; however, two additional boundary conditions must be imposed, namely, (1) the relative displacement of the upper and lower part of the joint element, $u_{3x} - u_{2x}$, cannot cause a gap closure (between deck and abutment) greater than the original gap dimension, and (2) frictional forces can be developed only when the relative displacement, $u_{1x} - u_{3x}$, causing a widening of the gap is less than the original "seat" dimension. As soon as the relative displacement $(u_{1x} - u_{3x})$ exceeds the original seat dimension, the bridge deck falls from its support; thus, the computer analysis is stopped at this point.

F. EQUIVALENT COLUMN FOR FOUNDATION

Various mathematical models have been used for structural foundations. As reported in the literature, Parmelee, Whitman and Roesset, Dobry, and others [81, 108] used a simple spring dashpot model; Jennings and Bielak and Richart, Hall, and Woods [58, 89] used the elastic half space; Whitman [109] used an equivalent lumped mass model; and, Dans and Butterfield, Finn, Lysmer and Kuhlemeyer, and Wilson [31, 36, 66, 114] used a finite element mesh. Various methods have been reported for estimating the lateral stiffness of foundations employing piles [84, 88].

The replacement of the foundation flexibility with an equivalent column through use of the elastic half space theory and under the assumption of quasi-static behavior has been reported by Penzien, et. al. [8]. This method has been adopted in the present investigations.

The first step in finding the equivalent column for the foundation is to determine the lateral, vertical, and rotational stiffnesses of the foundation at the footing (or pile cap) level. Once these three stiffnesses have been determined, the foundation is replaced by a column of length L, flexural stiffness EI, and axial stiffness AE which when fixed at its base provides the equivalent lateral, vertical, and rotational stiffnesses to the footing. The stiffness matrix for this column is given in the form of Eq. (23) under the assumption of no shear deformation, i.e. $\phi_y = 0$.

The foundation stiffnesses can be obtained by either the numerical procedure outlined by Penzien or by a closed form approach reported by Gerrand and Harrison [82, 39].

1. Closed Form Solution for Lateral Stiffness of Circular Footing - The closed form solution for lateral stiffness is available for a circular shaped footing as shown in Fig. 7-c. If the footing is rectangular in shape, an equivalent radius r_0 should be calculated for a circular footing having the same area, then

$$k_x = \frac{8\, r_0\, G}{2-\nu} \tag{32}$$

where

k_x = lateral stiffness for a single footing

r_0 = radius of footing

G = shear modulus of soil

ν = Poisson's ratio

For a pier of multiple supports, the interactions between footings are estimated by Eq. (33) which describes the lateral displacement at a distance r from a loaded footing.

$$u = T_h \frac{1}{4\pi r_0 G} \left[(2-\nu) \cdot \sin^{-1} \frac{1}{r} + \nu \cdot \frac{(r^2-1)^{\frac{1}{2}}}{r^2} \right] \qquad (33)$$

where

u = the displacement

T_h = the total applied force at a single footing

r = the distance in terms of radius r_0

By calculating the average displacement of all footings in a pier and dividing the total force by the average displacement, the equivalent stiffness of a pier with multiple footings is then obtained.

2. Numerical Solution Using the Mindlin Equation to Calculate Lateral Stiffness - The Mindlin equation has the following form. When the x component of displacement on the surface is to be calculated, as produced by a single concentrated force P located at the origin (o, o, o) on the surface of an isotropic half space and acting in the x-direction

$$u_x(x,y,o) = \frac{P(o,o,o)}{16\pi(1-\nu)G} \left\{ \frac{(3-4\nu)}{R} + \frac{1}{R} + \frac{4(1-\nu)(1-2\nu)}{R} + x^2 \left[\frac{1}{R^3} + \frac{3-4\nu}{R^3} - \frac{4(1-\nu)(1-2\nu)}{R^3} \right] \right\} \qquad (34)$$

in which

$$R^2 = x^2 + y^2$$

Under the assumption that the lateral force is uniformly distributed over the area of the footing, the procedure to calculate the lateral stiffness of a single footing is (1) replace the uniform pressure by as many concentrated loads P as accuracy requires, (2) calculate the lateral displacement of each load point over the footing area due to each concentrated load, (3) sum the resulting displacements at each load point within the footing as caused by the full set of loads, (4) average the load point displacements, and (5) divide the total resultant force by the average of the load point displacements to obtain the lateral stiffness.

Again, if a pier has many footings, the same averaging procedure is applied by assuming a concentrated force at the center of each footing; thus, the lateral stiffness of each pier foundation can be obtained.

3. Comparison of Two Methods for Lateral Stiffness - To compare the two previously described methods for obtaining foundation lateral stiffness, consider the pier shown in Fig. 8 having four footings. Assuming the footing is 8.5 x 8.5 ft and the distance between footings is 26 ft, the individual footing stiffness k_x and pier stiffness k_p obtained by the two approaches have the following values in k/ft:

$$k_x = \begin{cases} 32.5\ G & \text{Numerical method} \\ 25.5\ G & \text{closed form solution} \end{cases}$$

$$k_p = \begin{cases} 100.6\ G & \text{Numerical method} \\ 80.0\ G & \text{closed form solution} \end{cases}$$

Where the unit of G is in k/ft^2.

In each case the stiffnesses differ by approximately 20%. In the numerical solution the footing is considered to have 36 concentrated forces applied at equal grid intervals over the area. If the resultant force had been discritized at more than 36 points, the differences in stiffness would have decreased.

4. Vertical Stiffness with Friction Piles - Assuming the friction force per unit length of pile varies in a linear manner from a maximum value at the top to zero at the bottom, and assuming zero vertical displacement at the bottom of the pile, the vertical stiffness of the pile k_v is

$$k_v = 3AE/L \tag{35}$$

Where L, A, and E are the length, area, and modulus of elasticity, respectively, of the pile.

5. Vertical Stiffness Without Piles - Assuming uniform vertical displacements as shown in Fig. 7-a, the vertical stiffness of a circular footing without piles is given by

$$k_v = \frac{4\, r_0\, G}{1-\nu} \tag{36}$$

For other footing shapes, similar stiffness relations have been reported by Lysmer and Duncan [67].

6. Rotational Stiffness Without Piles - Assuming rotational displacements as shown in Fig. 7-b, the rotational stiffness of a circular footing without piles is given by

$$k_\theta = \frac{8\, r_0^3\, G}{3(1-\nu)} \tag{37}$$

The rotational stiffness of a rigid footing with piles can be calculated directly from the vertical stiffness of each pile.

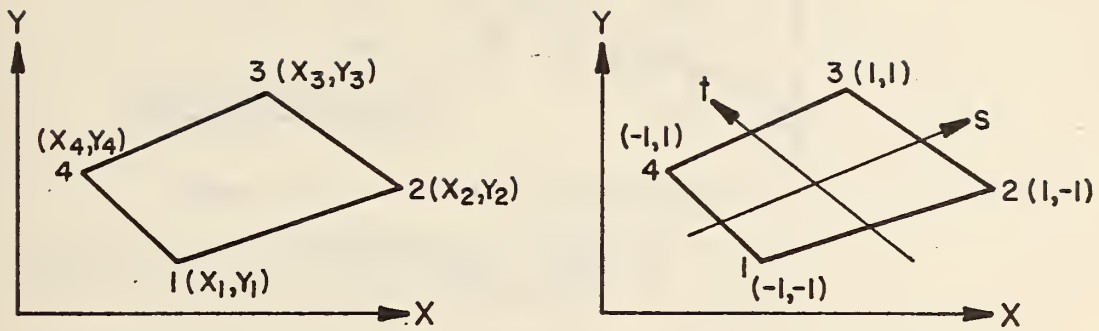


FIG. 2 TWO DIMENSIONAL ISOPARAMETRIC ELEMENT

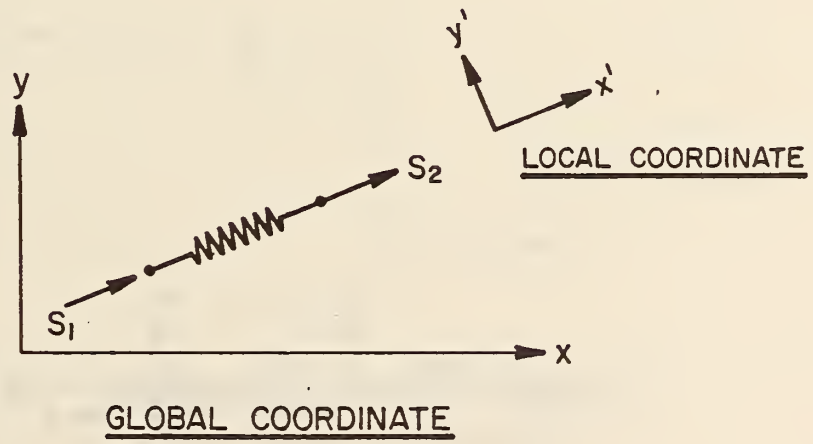


FIG. 3 BOUNDARY ELEMENT

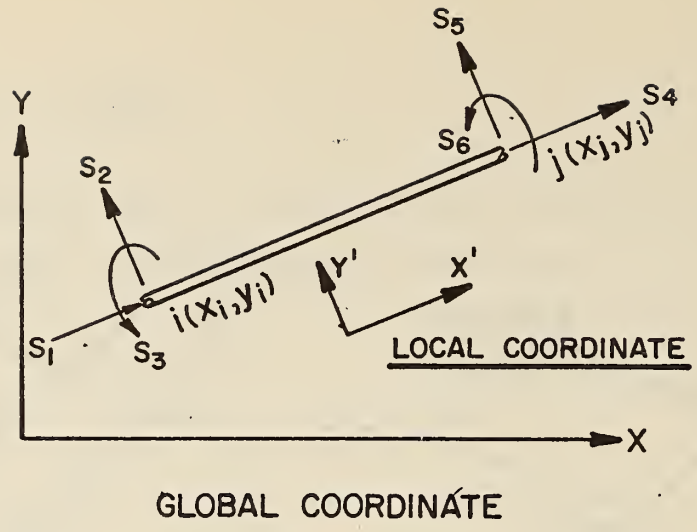


FIG. 4 BEAM ELEMENT COORDINATE SYSTEM

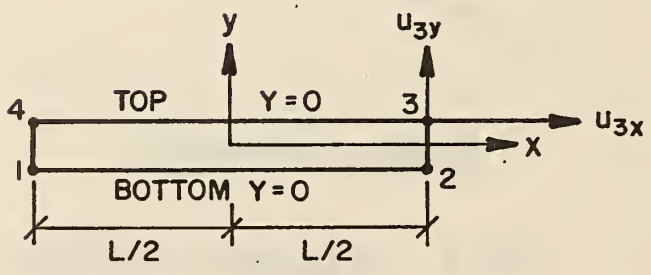
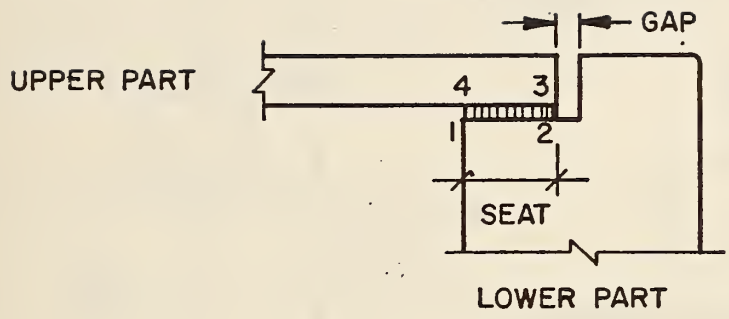
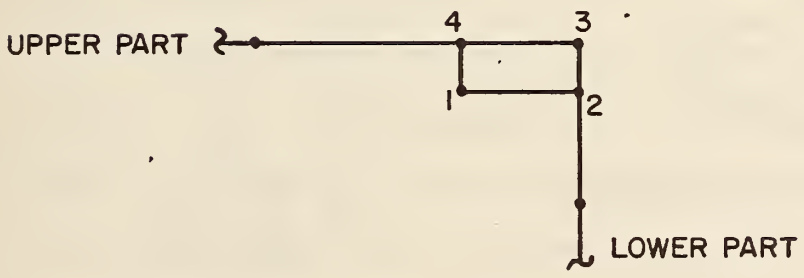


FIG. 5 FRICTIONAL ELEMENT, HEIGHT = 0
LOCAL COORDINATE

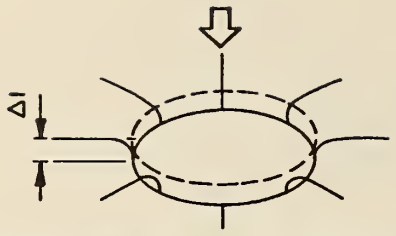


a. PROTOTYPE

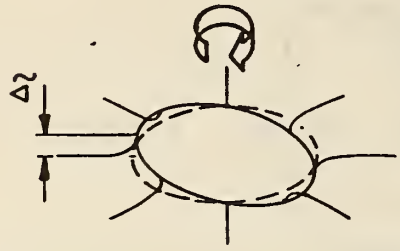


b. MODEL

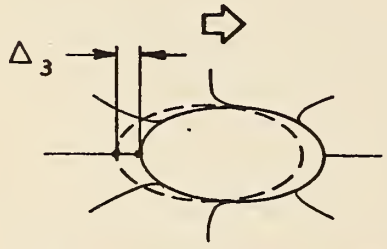
FIG. 6 EXPANSION JOINT ELEMENT



(a) UNIFORM VERTICAL DISPLACEMENT



(b) ROTATIONAL DISPLACEMENT



(c) LATERAL DISPLACEMENT

FIG. 7 DISPLACEMENT TYPES

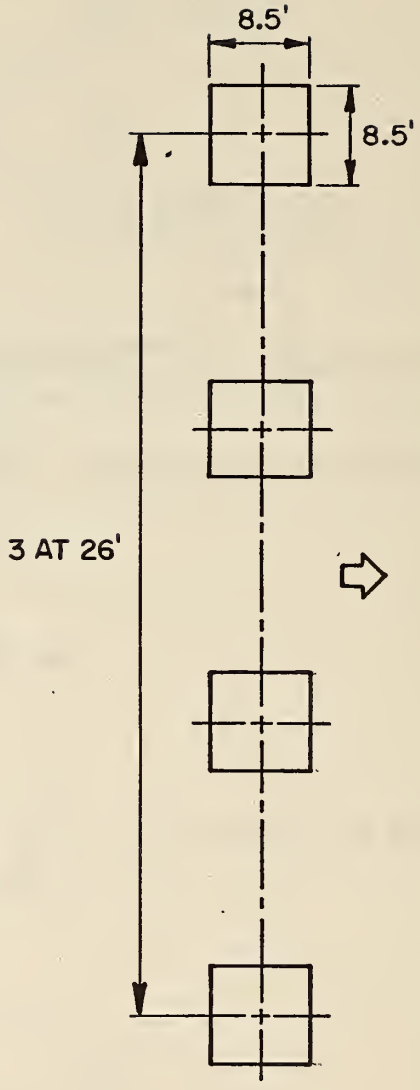


FIG. 8 PIER WITH FOUR COLUMNS

III MATERIAL PROPERTIES OF SOIL

In this chapter, the pertinent soil material properties used to establish a non-linear finite element model are discussed. The non-linear stress-strain relations, Mohr's envelope and p-q diagram, the concepts of active and passive stresses, and the damping characteristics of soil are described.

A. STRESS-STRAIN RELATIONSHIP

Basic to establishing the force-displacement relationships for soil elements as employed in the mathematical model are the stress-strain relationships for the materials involved. These materials include both cohesionless and cohesive soils.

Numerous authors, including Bishop and Henkel, Bishop, Comforth and Seed, have reported procedures for determining the shear modulus of sand [9, 10, 23, 96]. The investigators show that the shear modulus is strongly influenced by confining pressure, strain amplitude, and void ratio. In the present investigation, the equivalent secant shear modulus as determined by extreme points on the hysteresis loop, Fig. 9, is adopted. This modulus can be estimated using the relation proposed by Seed [96], namely,

$$G = 1000\, k_2\, (\sigma_m')^{\frac{1}{2}} \qquad \text{psf} \qquad (38)$$

where G is the secant modulus of sand, σ_m' is the effective mean stress and k_2 is a parameter which depends upon void ratio e and strain amplitude

as shown in Fig. 10. Triaxial tests show that k_2 depends only upon void ratio e at very low strain levels ($\gamma \leq 10^{-3}$ percent). At intermediate strain levels ($10^{-3} \leq \gamma \leq 10^{-1}$ percent), it still depends primarily upon void ratio but is also slightly influenced by state of stress and the friction angle ϕ. At very high strain levels, k_2 is essentially a constant which is almost independent of state of stress, friction angle, and the void ratio. Thus for practical purposes, the values of k_2 can be assumed to vary only with strain amplitude and void ratio as shown in Fig. 10.

For prescribed values of void ratio and confining pressure, the stress-strain relationship is non-linear with the shear modulus changing with shear strain. Upon the initiation of yielding the modulus becomes very small. A tangent modulus curve transformed from the equivalent shear modulus curve, Fig. 10, is shown in Fig. 12. Theoretically, one could use a revised tangent modulus over each time interval of a dynamic analysis; however, it is believed to be more practical to use a more simplified form of stress-strain relationship. In the present investigation a trilinear stress-strain relationship, Fig. 13-a, has been adopted with the shear modulus remaining constant during each of three different loading stages. In the initial stage, the soil element is in its geostatic state, i.e. the vertical stress is equal to the weight of soil (per unit area) above the point of interest as given by

$$\sigma_v = \int_0^y w \, dy \tag{39}$$

where y is the depth and w is the unit weight of soil. The lateral stress in the principal horizontal direction is

$$\sigma_h = k_0 \sigma_v \tag{40}$$

while in the orthogonal horizontal direction (z) the stress σ_z for plane stress is

$$\sigma_z = 0 \tag{41}$$

and for plane strain is

$$\sigma_z = \mu(\sigma_v + \sigma_h) = \frac{k_0}{1+k_0}(\sigma_v + k_0\sigma_v) = k_0\sigma_v = \sigma_h \tag{42}$$

where μ is Poisson's ratio. The shear modulus in this stage is evaluated by Eq. (38) with k_2 selected in accordance with the very low strain level shown in Fig. 10. In the second stage the soils in the backfill are no longer in the geostatic state due to loadings from the bridge. In this case the shear modulus is calculated using Eq. (38), but k_2 is revised to be consistent with the maximum shear strain in the element. The third stage occurs after the initiation of yielding in which case the stress-strain relation is evaluated in accordance with a theory of plasticity as described in Chapter IV.

In those cases where curves of k_2 vs. γ as shown in Fig. 10 are unavailable, a bilinear stress-strain relationship is adopted with the initial modulus being estimated by an empirical method and the second stage modulus being calculated by the theory of plasticity as shown in Fig. 13-b.

Turning our attention now to certain clay materials, test data show that at very low strain levels, the shear modulus varies almost linearly with shear strength [112]. In a summary report, Seed has presented a curve of secant shear modulus versus shear strain for

saturated clays [96]. The shear modulus expressed by this curve, Fig. 14, is in the normalized form G/s_u where s_u is the undrained shear strength of the material. A curve showing the degradation of secant shear modulus with shear strain, as obtained by a number of investigators, is shown in Fig. 11 [96]. These relationships can be used as a guide for estimating the initial modulus of clay when laboratory test data on the specific material are unavailable.

Fig. 15 gives a tangent modulus curve for clay which is consistent with the secant modulus curve of Fig. 11. Test results show that the shear modulus is essentially independent of the confining pressure. A re-evaluation of shear modulus before the initiation of yielding becomes much less important for this material than for sand. For this reason, a bilinear stress-strain relation has been assumed for cohesive soils in the present investigation. This initial modulus is estimated from the data previously described and the tangent stiffness after yielding is obtained using the same basic procedure as used for sands. No hardening effects after the initiation of yielding are considered.

B. MOHR'S ENVELOPE, p-q DIAGRAM

The most widely used yield criterion in soil mechanics is the Mohr-Coulomb criterion which relates the normal stress σ_f and the shear stress τ_f at the failure plane by the equation

$$\tau_f = c + \sigma_f \tan \phi \tag{43}$$

where c is the cohesion of the soil and ϕ is its friction angle. The soil coefficients are usually obtained by conducting triaxial tests at

various confining pressures and by drawing a common tangent line to the resulting Mohr's circles as shown in Fig. 16. It should be noted that since the confining pressure of the triaxial test is uniform, i.e. $\sigma_2 = \sigma_3$, the Mohr's circle can be used in its familiar two-dimensional form. Equation (43) when plotted on the σ-τ plane is called Mohr's yield envelope which implies (1) elastic behavior for a state of stress whose Mohr's circle lies entirely below the envelope, (2) yielding, or impending yielding, for a state of stress whose Mohr's circle has the envelope as its tangent, and (3) that any state of stress whose Mohr's circle crosses the envelope is not permitted.

An alternate way of plotting the results of triaxial tests is to plot the stresses at the plane of maximum shear on the p-q plane, namely,

$$p = \frac{\sigma_1 + \sigma_3}{2} \tag{44}$$

and

$$q = \frac{\sigma_1 - \sigma_3}{2} \tag{45}$$

In Fig. 17, points A, B, and C in the σ-τ plane represent the stresses on planes of maximum shear. A line drawn through these same points in the p-q plane, as shown in Fig. 18, is called the k_f line. The equation of this line is

$$q_f = a + p_f \tan \alpha \tag{46}$$

Strength parameters c and ϕ can be computed from Eq. (46) through the relations

$$\sin \phi = \tan \alpha \tag{47}$$

$$c = a/\cos \phi \qquad (48)$$

C. ACTIVE AND PASSIVE STRESS

Using the previously defined yield criterion, active and passive soil stresses can be defined as they relate to the backfill pressures exerted on abutment walls. Starting with soil equilibrium in its geostatic state which has principal axes in the vertical and horizontal directions, decrease the horizontal compressive stress continually until the shear strength of the soil is reached and failure occurs. The horizontal compressive stress at the point of failure is active stress. On the other hand, if the horizontal compressive stress is continually increased, the shear strength of the soil will again be reached at a much higher stress level called the passive stress. The Mohr's circles representing these two failure conditions are shown in Fig. 19 where σ_v and σ_h represent the vertical and horizontal stresses, respectively, in the geostatic state and σ_a and σ_p represent the active and passive stresses, respectively. It should be noted here that since the two horizontal stresses are assumed equal, only two stress components are required to describe the stress conditions.

The stress conditions in the σ-τ diagram of Fig. 19 are again shown in the p-q diagram of Fig. 20, where point A is the geostatic state of stress, point B is the passive state of stress, and point C is the active state of stress. Lines AC and AB are stress paths which depict the successive states of stress which occur in changing from the geostatic condition to the active and passive conditions, respectively.

When applying the concepts of active and passive stresses to more complex stress conditions, certain modifications are needed. For example, the stress conditions of the bridge backfill-soil treated in this investigation is essentially three-dimensional. In this case shear stresses may exist on both vertical and horizontal planes even under gravity loadings. Referring to Figs. 1-A and B for the element coordinates, the Mohr's circle for this condition may be as shown in Fig. 21. Further, it should be noted that if the side slopes of the embankment as seen in Fig. 1-B are not sufficiently flat, the yield plane will show as a line in the y-z plane. In the present study however it is assumed that these slopes are sufficiently flat so that the yield plane shows as a line in the x-y plane. Thus the state of stress at failure as shown on an element of soil in the x-y plane, can be represented by a Mohr's circle tangent to the Mohr's envelope as shown by Circle 1 in Fig. 22. States of stress in the x-z and y-z planes would be represented by Mohr's circles falling entirely within the above defined circle as shown by Circle II and III in Fig. 22. Because of these restrictions, the problem can be treated as a two-dimensional problem in the x-y plane. Finally, in the present investigation, all stresses vary prior to reaching a state of yield. Based on the previous assumptions, active and passive states can be defined in an equivalent manner. Referring to Fig. 23 where the absolute values of the p and q stresses are plotted, p values at static loading and failure conditions can be compared. If $|p|$ is assumed to decrease continually with increasing $|q|$ stress until the Mohr's envelope is reached, active failure occurs. On the other hand, if $|p|$ is assumed to increase continually with increasing $|q|$ stress until the envelope is reached, passive failure

occurs. Stresses p_a and p_p represent the active and passive stresses in this case.

D. DAMPING

Soils, like all materials, exhibit energy dissipation when subjected to cyclic loading. Different methods have been used for measuring damping depending upon the strain levels involved [96]. Forced vibration tests have been used for strain levels in the range 10^{-4} to 10^{-2} percent, free vibration tests have been used for strain levels in the range 10^{-3} to 1.0 percent, and static tests have been used to measure the hysteretic energy absorption for strain levels in the range 10^{-2} to 5 percent. The energy dissipation in the latter case has been expressed in terms of equivalent viscous damping ratios [102, 103].

Experimental evidence shows that two major factors influence the amount of damping exhibited by sands, namely, confining pressure and strain amplitude. Damping in this case tends to decrease with an increase in confining pressure and tends to increase with strain amplitude. Clay materials, on the other hand, exhibit damping which is essentially independent of confining pressure but, like sands, the damping increases with strain amplitude.

In modelling the damping as measured in soils, it has generally been carried out by using an equivalent viscous damping system. An important basic study carried out along these lines, using a wide range of yield values, has been reported by Hudson [47]; see Fig. 24. In this case, the equivalent viscous damping ratio corresponding to elasto-plastic hysteretic damping for a single degree of freedom system

is given.

In the present investigation, hysteretic damping has not been converted to an equivalent viscous form. Rather, it is treated in its true strain dependent form. Since hysteretic damping treated in this manner accounts for energy dissipation only for strain levels above yield, it is necessary to also include viscous damping to represent the low strain level velocity dependent damping. For this purpose, Rayleigh damping has been used in the present investigation.

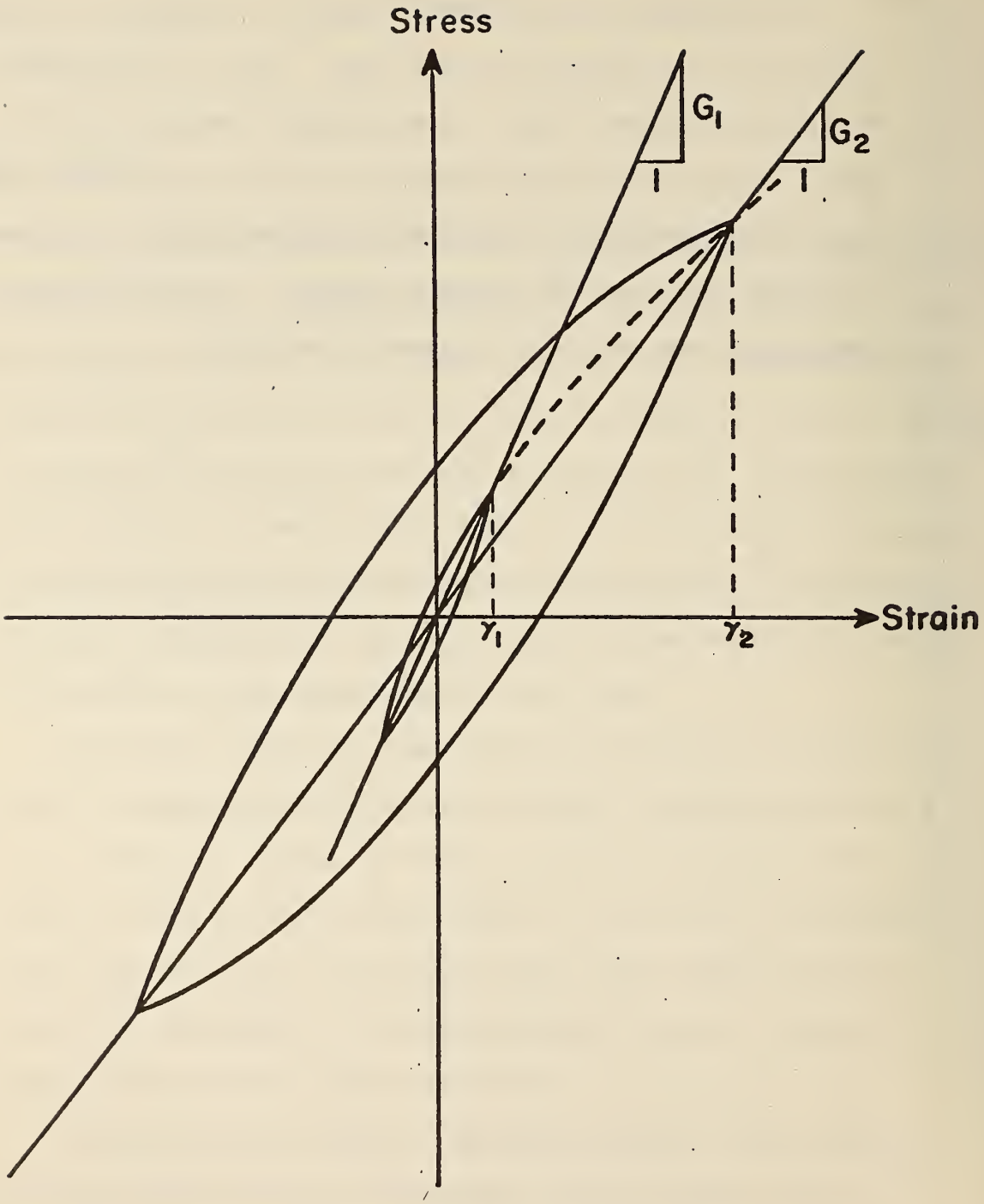


FIG. 9 HYSTERETIC STRESS-STRAIN RELATIONSHIPS AT DIFFERENT STRAIN AMPLITUDES-SECANT MODULUS

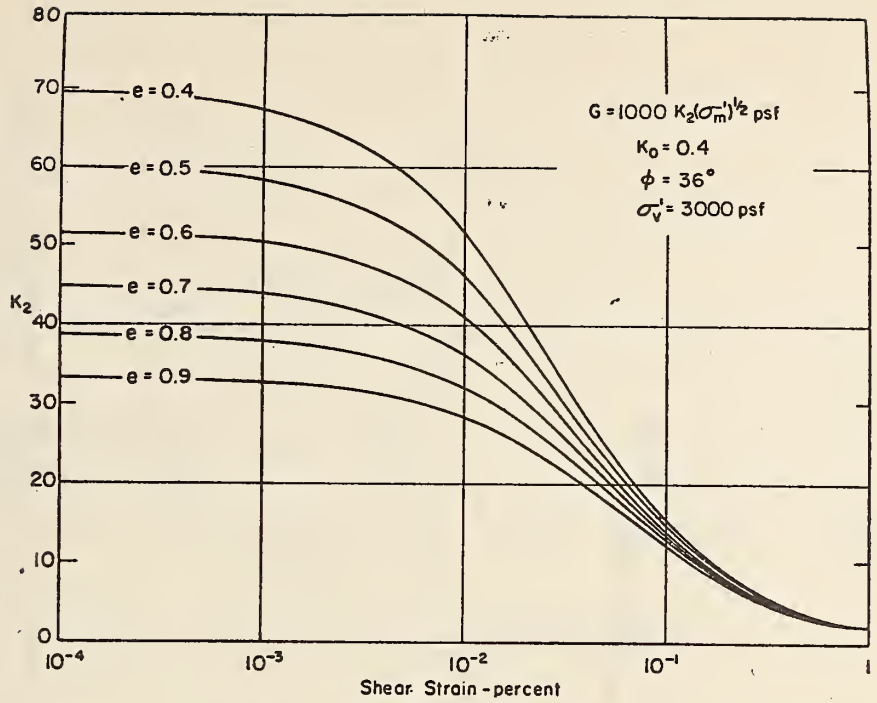


FIG. 10 SECANT SHEAR MODULI OF SANDS AT DIFFERENT VOID RATIOS
(After Seed and Idriss)

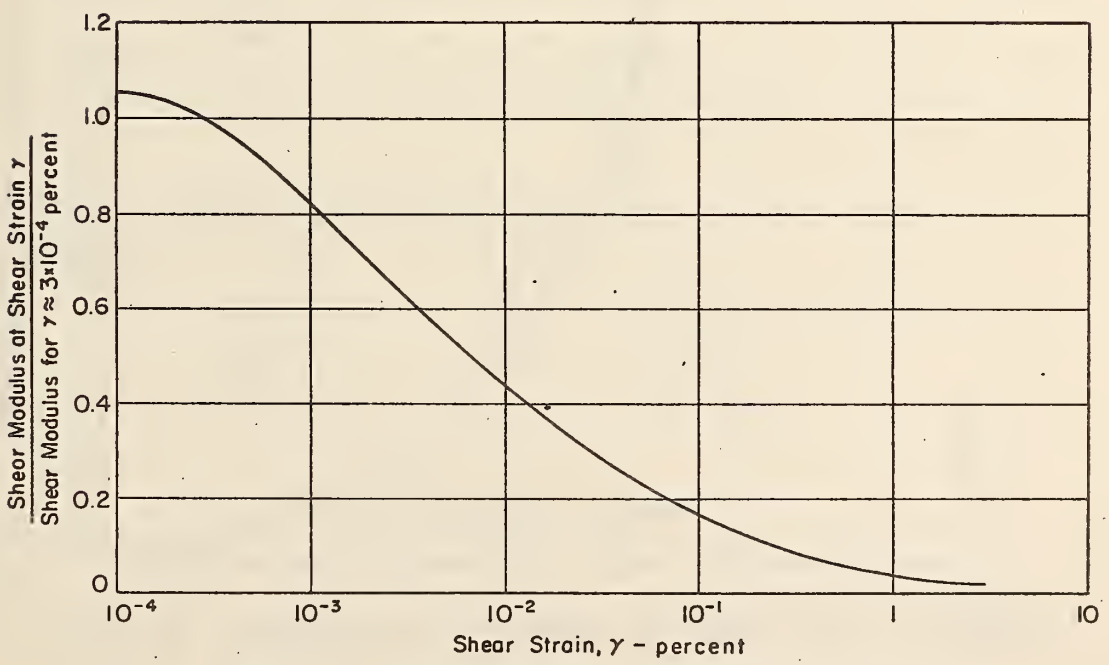


FIG. 11 TYPICAL REDUCTION OF SECANT SHEAR MODULUS WITH SHEAR STRAIN FOR SATURATED CLAYS
(After Seed and Idriss)

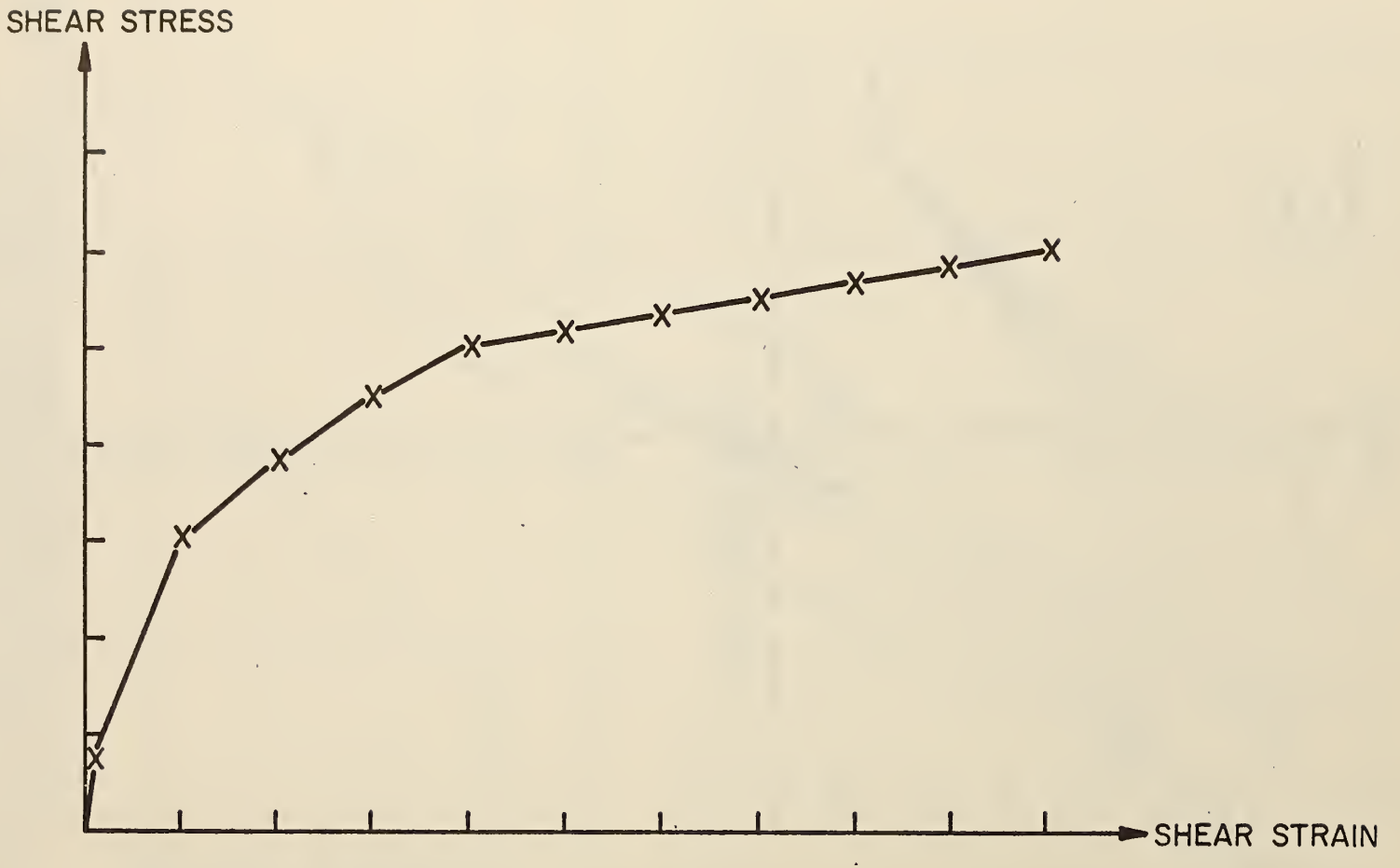
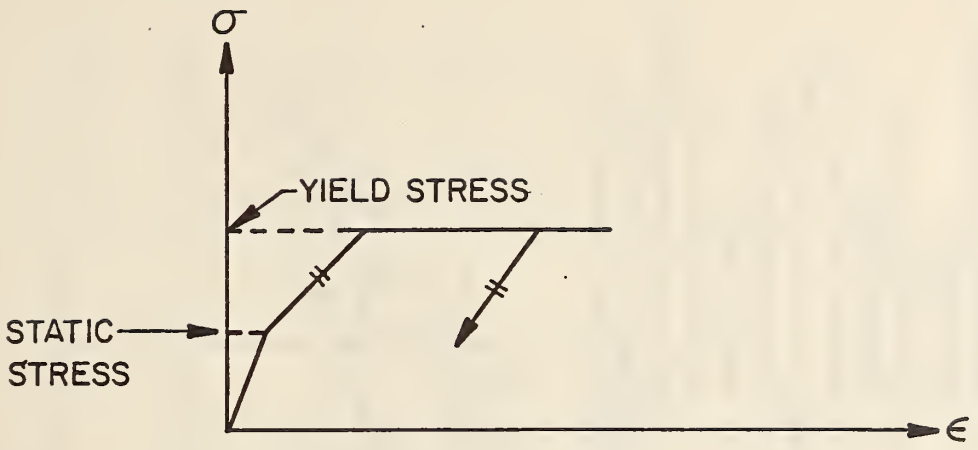
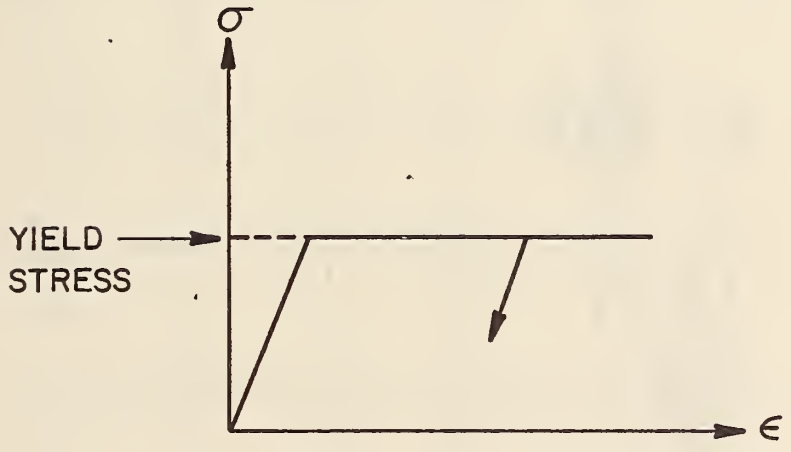


FIG. 12 VARIATION OF TANGENT MODULUS WITH SHEAR STRAIN FOR SAND



(a) TRILINEAR CURVE



(b) BILINEAR CURVE

FIG. 13 IDEALIZED STRESS-STRAIN RELATIONSHIP

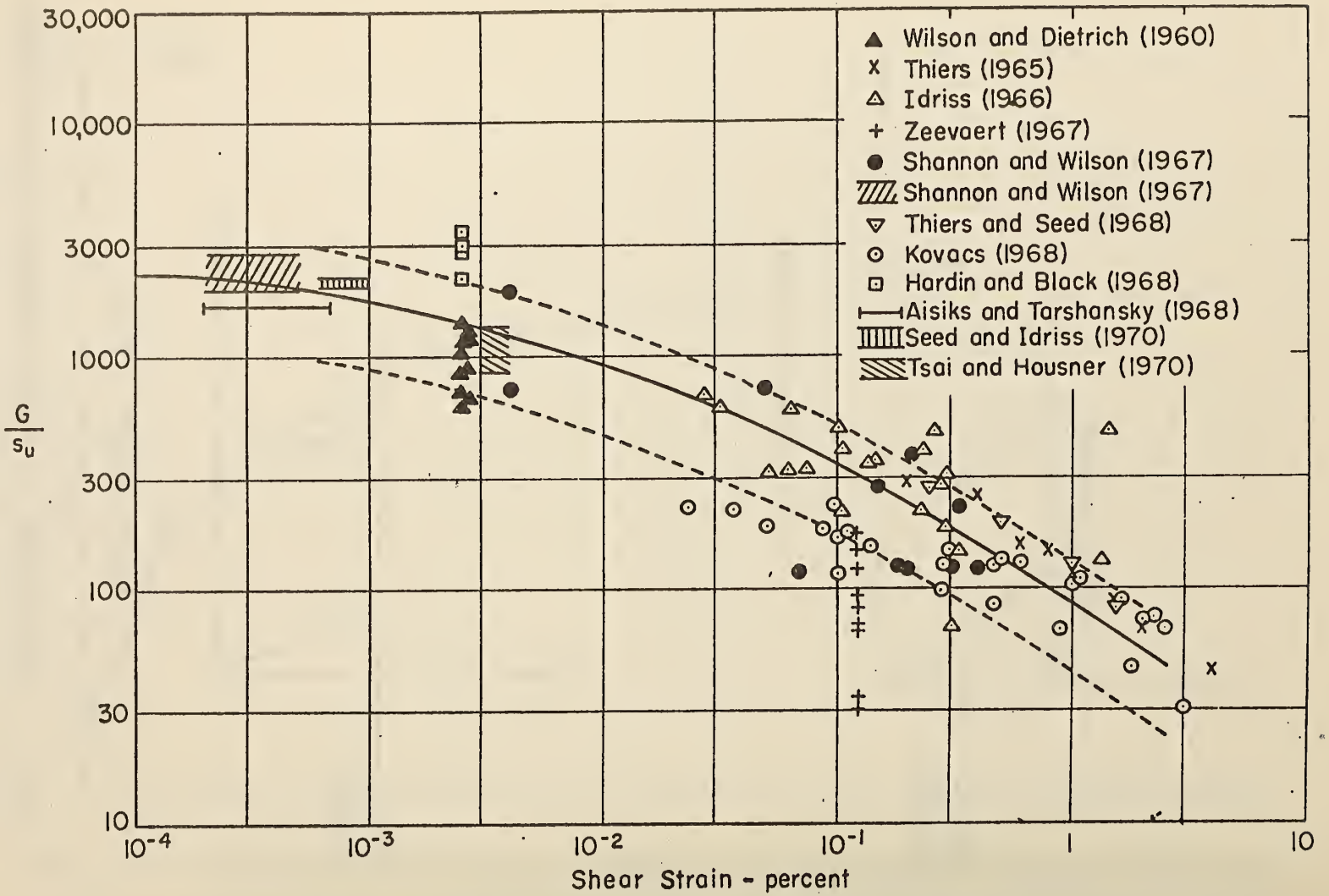


FIG. 14 IN-SITU SECANT SHEAR MODULI FOR SATURATED CLAYS

(After Seed and Idriss)

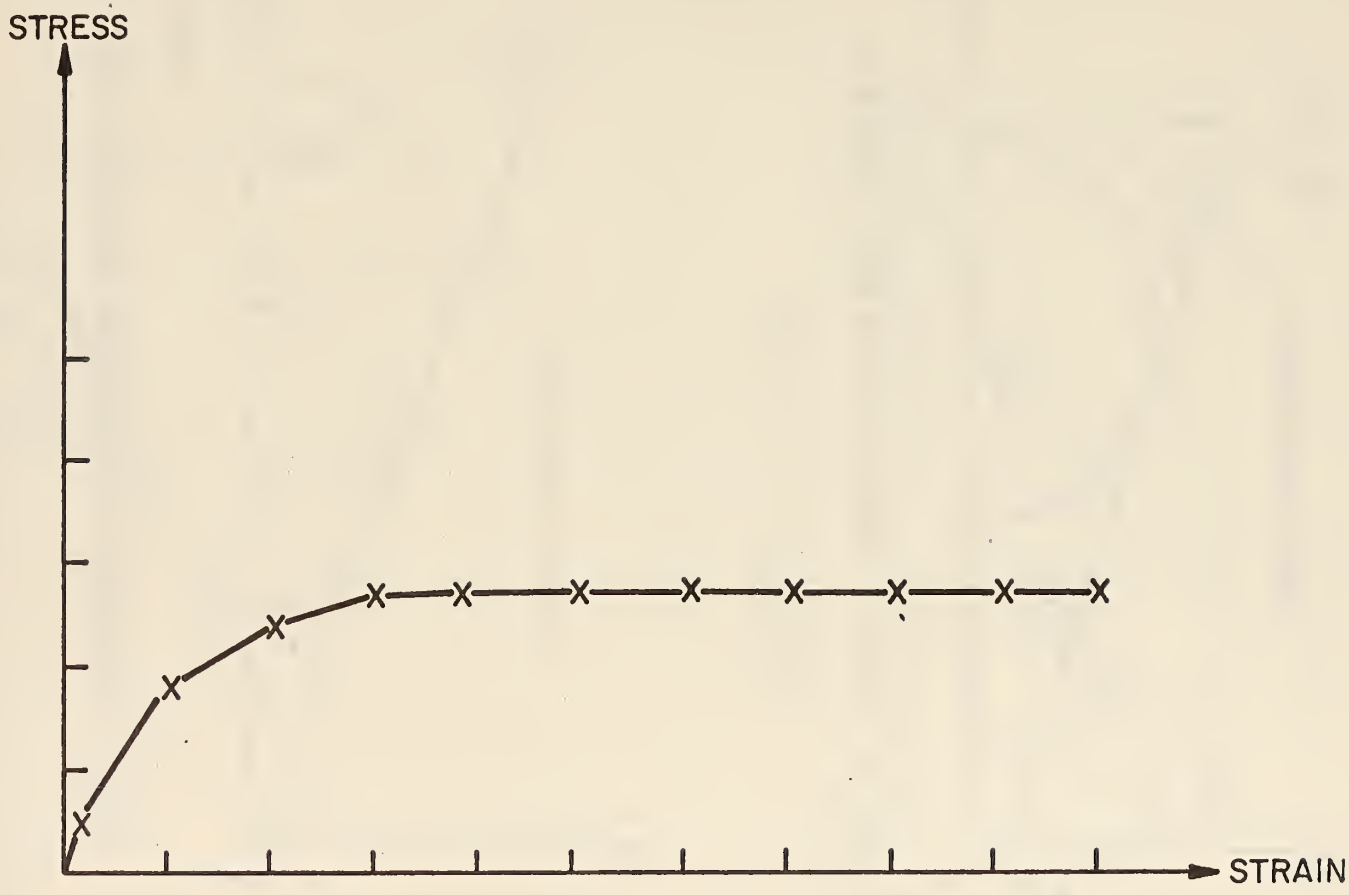


FIG. 15 VARIATION OF TANGENT MODULUS WITH SHEAR STRAIN FOR CLAYS

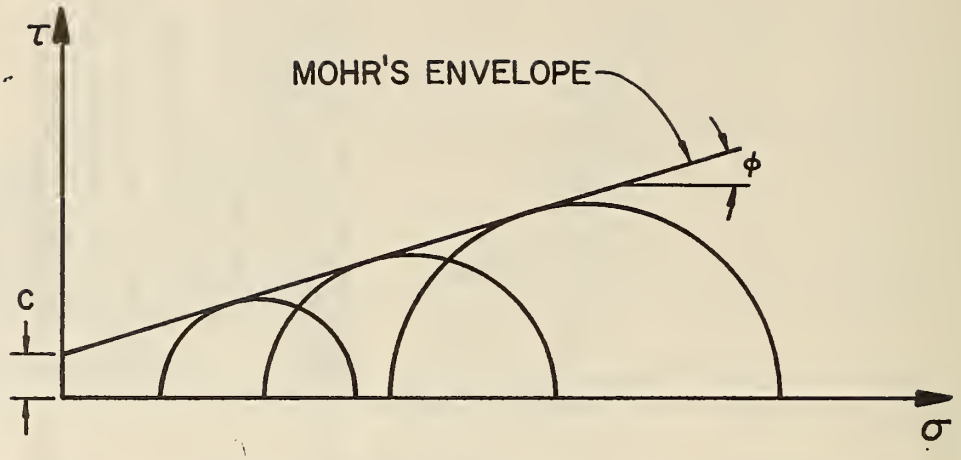


FIG. 16 MOHR'S ENVELOP FOR SOIL SAMPLE

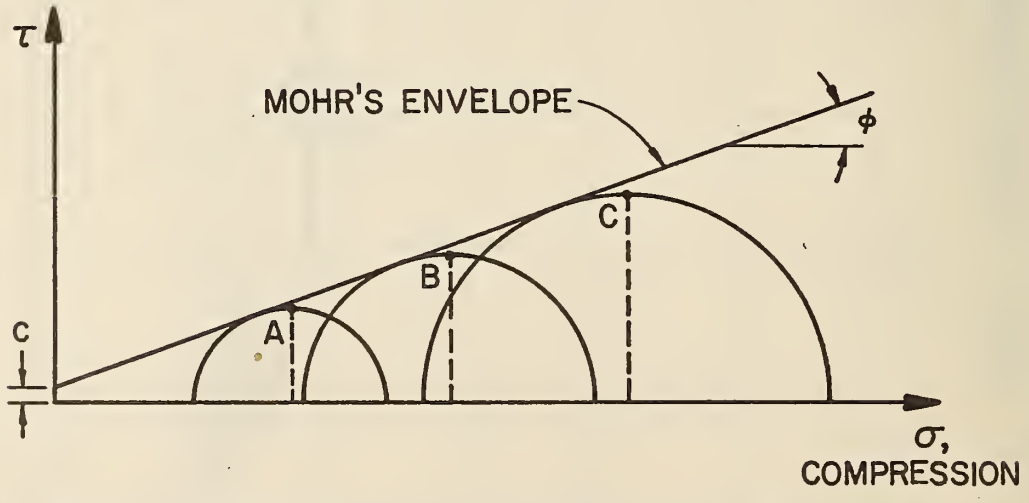


FIG. 17 STRESSES AT MAXIMUM SHEAR PLANE

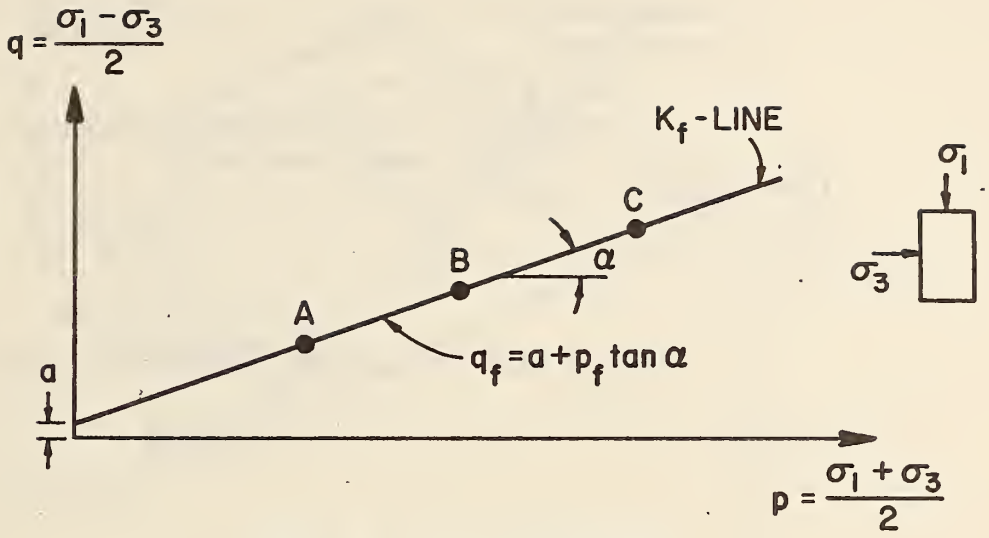


FIG. 18 p-q DIAGRAM

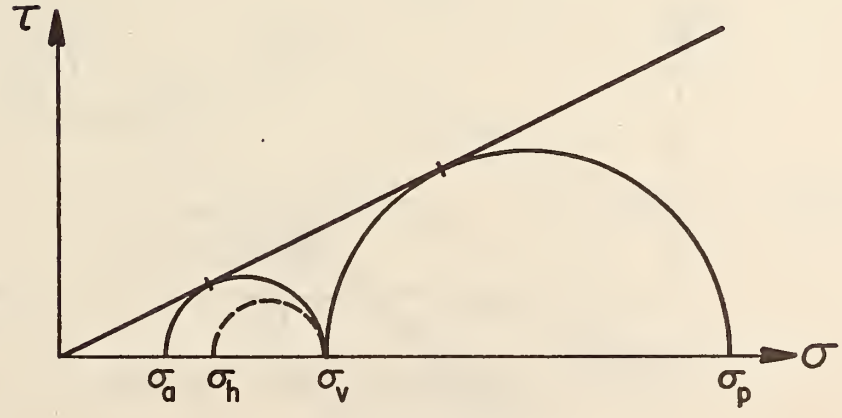


FIG. 19 MOHR CIRCLE

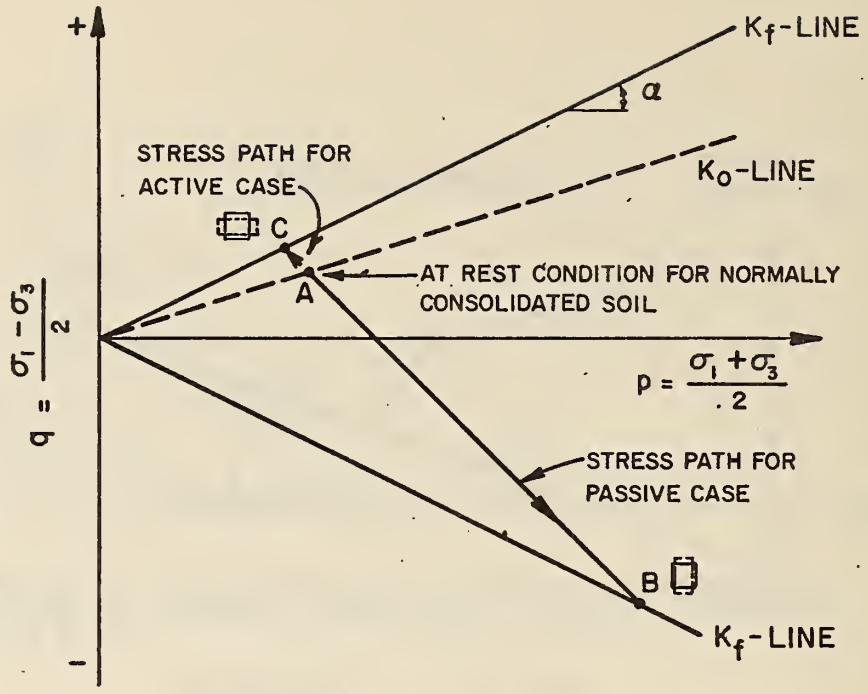


FIG. 20 STRESS PATHS FOR RANKINE ACTIVE AND PASSIVE CONDITIONS

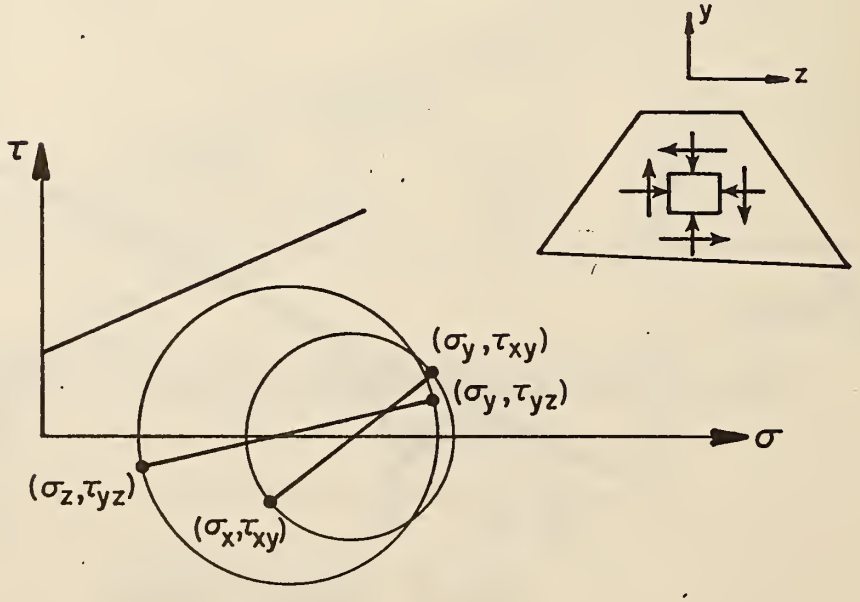


FIG. 21 STRESS CONDITIONS AT FIELD

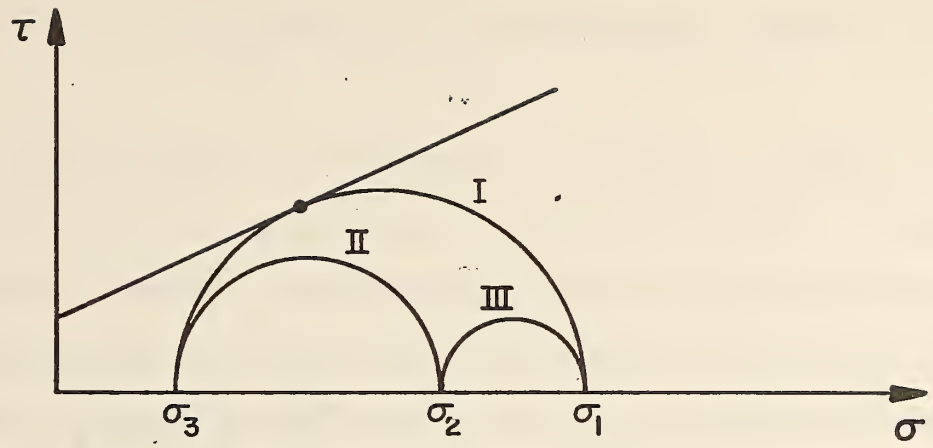


FIG. 22 MOHR CIRCLE IN 3 PLANES

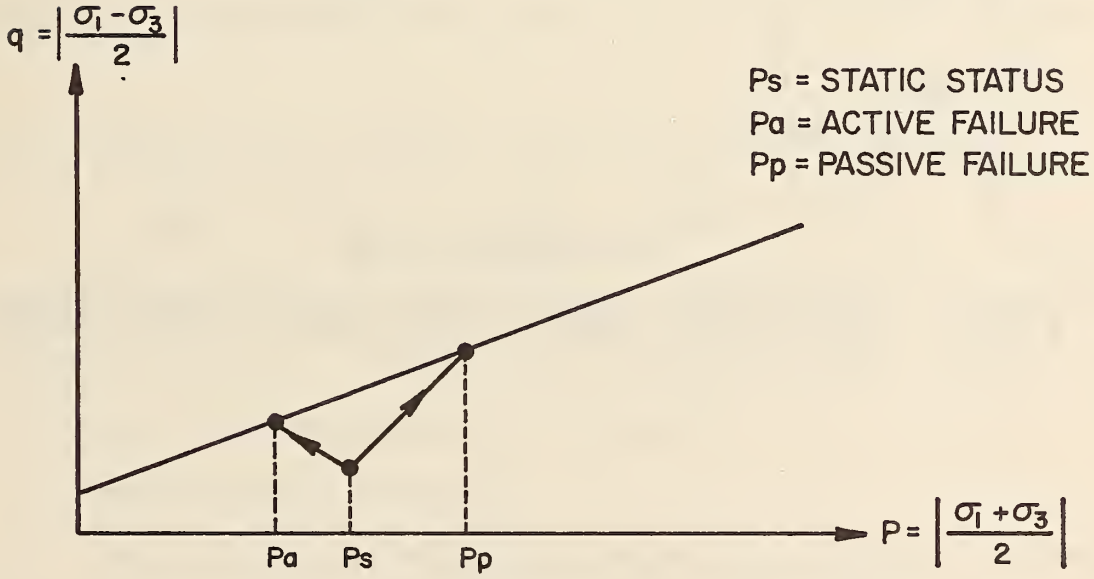


FIG. 23 ACTIVE AND PASSIVE FAILURE

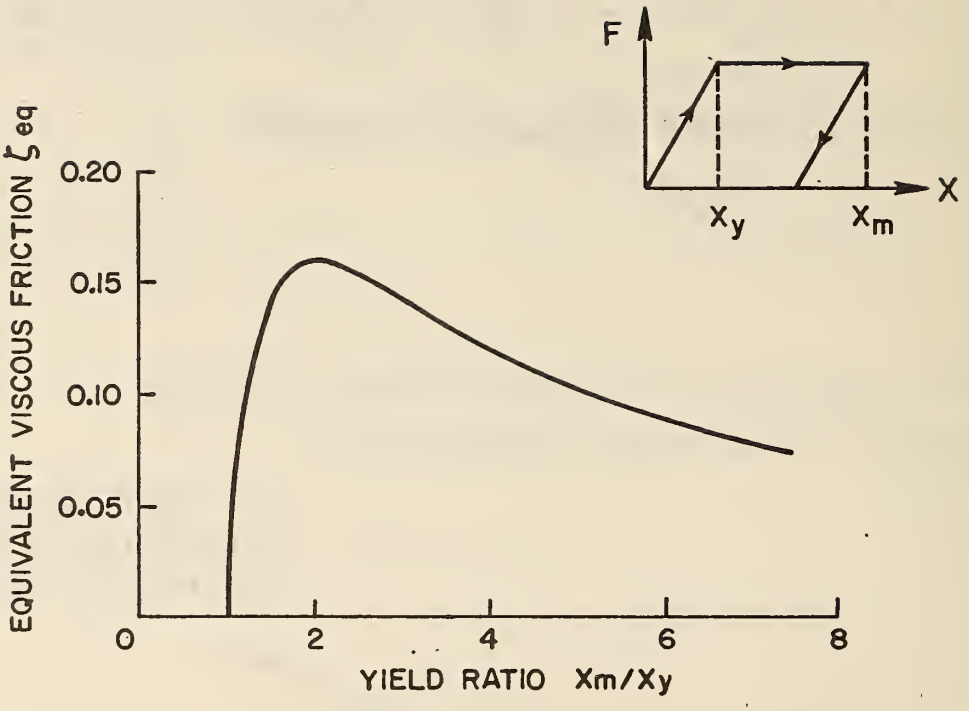


FIG.24 EQUIVALENT VISCOUS FRICTION VS YIELD RATIO

IV NON-LINEAR STIFFNESSES OF MODEL ELEMENTS

During periods of low amplitude oscillation, a bridge-soil system can be modelled using the linear elements as described in Chapter II. It may be necessary in this case to treat the friction and expansion joint elements in a piece-wise linear fashion. For a severe earthquake however inelastic deformations may occur in the concrete columns and/or backfill soils, separations and impacts may develop between the abutments and backfills, slippages may take place in the expansion joints, and yielding may take place at the soil boundaries or in the foundation to complicate the behavior.

It is the purpose of this chapter to describe the non-linear behaviors of all elements and to derive their non-linear stiffnesses.

A. GENERAL ELASTIC-PERFECTLY PLASTIC STRESS-STRAIN RELATIONS

Presently, extensive literature exists on the theory of plasticity and its application to different types of materials and structural elements [30, 46, 85]. Recently, its application has been extended to soil structures and frame structures as reported by Dibaj and Penzien, and by Porter and Powell [28, 83].

The first step in deriving the stress-strain relations for an elastic-perfectly plastic material is to assume a yield function expressed in terms of the stress space. This stress function can be expressed as

$$f(\tau_{ij}) = 0 \tag{49}$$

By application of the flow rule, the plastic strain increment tensor is derivable from this function using the relation

$$\delta \varepsilon^{P}_{ij} = \lambda \frac{\partial f}{\partial \tau_{ij}} \tag{50}$$

where λ is a non-negative scale factor. The total strain increment tensor is thus decomposed into its elastic and plastic components as expressed by

$$\delta \varepsilon_{ij} = \delta \varepsilon^{E}_{ij} + \delta \varepsilon^{P}_{ij} \tag{51}$$

The generalized Hooke's law, relating the increment of stress tensor to the increment of elastic strain tensor, can be written in the form

$$\delta \tau_{ij} = C^{E}_{ijk\ell} \delta \varepsilon^{E}_{ij} \tag{52}$$

Using Eq. (51), Eq. (52) can be rewritten as

$$\delta \tau_{ij} = C^{E}_{ijk\ell} (\delta \varepsilon_{k\ell} - \delta \varepsilon^{P}_{k\ell}) \tag{53}$$

For an elastic-perfectly plastic material

$$\delta f = \frac{\partial f}{\partial \tau_{ij}} \delta \tau_{ij} = 0 \tag{54}$$

Substituting Eqs. (53) and (50) into Eq. (54), one obtains

$$\frac{\partial f}{\partial \tau_{ij}} C^{E}_{ijk\ell} (\delta \varepsilon_{k\ell} - \delta \varepsilon^{P}_{k\ell}) = 0 \tag{55}$$

or

$$\frac{\partial f}{\partial \tau_{ij}} C^{E}_{ijk\ell} \delta \varepsilon_{k\ell} - \frac{\partial f}{\partial \tau_{ij}} C^{E}_{ijk\ell} \frac{\partial f}{\partial \tau_{k\ell}} \lambda = 0 \tag{56}$$

Solving for λ gives

$$\lambda = h\, C^{E}_{ijk\ell}\, \frac{\partial f}{\partial \tau_{ij}}\, \delta\, \varepsilon_{k\ell} \tag{57}$$

where

$$\frac{1}{h} = C^{E}_{ijk\ell}\, \frac{\partial f}{\partial \tau_{ij}}\, \frac{\partial f}{\partial \tau_{k\ell}} \tag{58}$$

Substituting Eq. (57) into Eq. (50) results in the relation

$$\delta\, \varepsilon^{P}_{ij} = h\, C^{E}_{mnk\ell}\, \frac{\partial f}{\partial \tau_{mn}}\, \delta\, \varepsilon_{k\ell}\, \frac{\partial f}{\partial \tau_{ij}} \tag{59}$$

A further substitution of this relation into Eq. (53) gives

$$\delta\, \tau_{ij} = C^{E}_{ijk\ell}\, (\delta\, \varepsilon_{k\ell} - h\, C^{E}_{ijmn}\, \frac{\partial f}{\partial \tau_{ij}}\, \frac{\partial f}{\partial \tau_{k\ell}}\, \delta\, \varepsilon_{mn}) \tag{60}$$

or

$$\delta\, \tau_{ij} = C^{E}_{ijk\ell}\, (\delta\, \varepsilon_{k\ell} - A_{k\ell mn}\, \delta\, \varepsilon_{mn}) \tag{61}$$

where

$$A_{k\ell mn} = h\, C^{E}_{ijk\ell}\, \frac{\partial f}{\partial \tau_{ij}}\, \frac{\partial f}{\partial \tau_{mn}} \tag{62}$$

The final form of the stress-strain relation for elasto-perfectly plastic material can now be written in the form

$$\delta\, \tau_{ij} = C_{ijk\ell}\, \delta\, \varepsilon_{k\ell} \tag{63}$$

where

$$C_{ijk\ell} = C^{E}_{ijk\ell} - C^{E}_{ijmn}\, A_{k\ell mn} \tag{64}$$

and where

$$C^{P}_{ijk\ell} = C^{E}_{ijmn} A_{k\ell mn} \tag{65}$$

B. SOIL FINITE ELEMENT

The Mohr-Coulomb criterion as stated in Eq. (43) of Chapter III may be expressed in terms of the principal stresses, namely

$$(\sigma_1 - \sigma_3) + (\sigma_1 + \sigma_3) \sin \phi = 2c \cos \phi \tag{66}$$

where $\sigma_1 \geq \sigma_2 \geq \sigma_3$ with tension as positive. In the case of two dimensional stress in the x,y plane, this relationship takes the form

$$(\sigma_x + \sigma_y) \sin \phi + 2R - 2c \cos \phi = 0 \tag{67}$$

where

$$R = \left[\left(\frac{\sigma_x - \sigma_y}{2} \right)^2 + (\tau_{xy})^2 \right]^{\frac{1}{2}} \tag{68}$$

is the radius of the failure stress circle as shown in Fig. 25.

1. Tangent Stiffness In Plain Strain - The derivative of tangent stiffness given by Eqs. (49) through (65) will now be presented in matrix form for the case of plain strain. Using the Mohr-Coulomb criterion as the yield function $f(\tau_{ij})$, and the index notation for stresses such that $\tau_{11} = \sigma_x$, $\tau_{22} = \sigma_y$, and $\tau_{12} = \tau_{xy}$, one obtains

$$f = (\tau_{11} + \tau_{22}) \sin \phi + 2 \left[\left(\frac{\tau_{11} - \tau_{22}}{2} \right)^2 + \tau_{12}^2 \right]^{\frac{1}{2}} - 2c \cos \phi = 0 \tag{69}$$

and

$$q_{ij} = \frac{\partial f}{\partial \tau_{ij}} \tag{70}$$

Equation (50) becomes

$$\{\delta\varepsilon^P\} = \lambda\{q\} \tag{71}$$

where

$$\{q\}^T = < q > = < q_{11}\ q_{22}\ q_{12} >$$

$$= < [\frac{1}{2}\sin\phi + (\frac{\tau_{11} - \tau_{12}}{R})], [\frac{1}{2}\sin\phi - (\frac{\tau_{11} - \tau_{22}}{R})],$$

$$[2\frac{\tau_{12}}{R}] > \tag{72}$$

Equation (51) in matrix form can be written as

$$\{\delta\ \varepsilon\} = \{\delta\ \varepsilon^E + \delta\ \varepsilon^P\} \tag{73}$$

where

$$\{\delta\ \varepsilon\}^T = <\delta\ \varepsilon> = < \delta\ \varepsilon_{11}\ \delta\ \varepsilon_{22}\ \delta\ \varepsilon_{12} >$$

$$\{\delta\ \varepsilon^P\}^T = < \delta\ \varepsilon^P > = < \delta\ \varepsilon^P_{11}\ \delta\ \varepsilon^P_{22}\ \delta\ \varepsilon^P_{12} >$$

$$\{\delta\ \varepsilon^E\}^T = < \delta\ \varepsilon^E > = < \delta\ \varepsilon^E_{11}\ \delta\ \varepsilon^E_{22}\ \delta\ \varepsilon^E_{12} >$$

$$\{\delta\ \tau\} = [C^E]\ \{\delta\ \varepsilon^E\}$$

and where

$$\{\delta\ \tau\}^T = < \delta\ \tau> = < \delta\ \tau_{11}\ \delta\ \tau_{22}\ \delta\ \tau_{12} > \tag{74}$$

$$[C^E] = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & 0 \\ \nu & 1-\nu & 0 \\ 0 & 0 & \frac{1-2\nu}{2} \end{bmatrix} \tag{75}$$

$$\lambda = h\{q\}^T [C^E] \{\delta \varepsilon\} \tag{76}$$

$$\frac{1}{h} = \{q^T\} [C^E] \{q\}$$

$$= \frac{E}{1+\nu} \left[\frac{\sin^2 \phi}{2(1-2\nu)} + \frac{1}{2} + \frac{3}{2} \frac{\tau_{12}^2}{R^2} \right] \tag{77}$$

$$\frac{1}{h} = \frac{E\ B}{1+\nu} \tag{78}$$

where

$$B = \frac{\sin^2 \phi}{2(1-2\nu)} + \frac{1}{2} + \frac{3}{2} \frac{\tau_{12}^2}{R^2} \tag{79}$$

Equations (62) through (65) in matrix form become

$$[A] = h \{q\} \{q\}^T [C^E] \tag{80}$$

$$\{\delta \tau\} = [C] \{\delta \varepsilon\} \tag{81}$$

$$[C] = [C^E] - [C^E][A]$$

$$= [C^E] - h[C^E] \{q\} \{q^T\} [C^E]$$

$$= [C^E] - [C^P] \tag{82}$$

Letting

$$\{Q\}^T = \{q\}^T [C^E]$$

$$= \frac{E}{1+\nu} < Q_1\ Q_2\ Q_3 >$$

$$= \frac{E}{1+\nu} < \frac{\sin \phi}{2(1-2\nu)} + \frac{\tau_{11} - \tau_{12}}{4R}, \frac{\sin \phi}{2(1-2\nu)} - \frac{\tau_{11} - \tau_{22}}{4R}, \frac{\tau_{12}}{R} > \tag{83}$$

, the matrix $[C^P]$ can be expressed in the form

$$[C^P] = h[C^E]\{q\}\{q\}^T[C^E]$$

$$= h\{Q\}\{Q\}^T$$

$$= \frac{E}{B(1+\nu)} \begin{bmatrix} Q_1^2 & Q_1Q_2 & Q_1Q_3 \\ Q_2Q_1 & Q_2^2 & Q_2Q_3 \\ Q_3Q_1 & Q_3Q_2 & Q_3^2 \end{bmatrix} \tag{84}$$

Finally, the tangent stiffness in explicit matrix notation becomes

$$[C] = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & 0 \\ \nu & 1-\nu & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} - \frac{E}{B(1+\nu)} \begin{bmatrix} Q_1^2 & Q_1Q_2 & Q_1Q_3 \\ Q_2Q_1 & Q_2^2 & Q_2Q_3 \\ Q_3Q_1 & Q_3Q_2 & Q_3^2 \end{bmatrix} \tag{85}$$

2. Postulate for Application of Tangent Stiffness to the Case of Plane Stress - In order to use the previously derived tangent stiffness for the case of plane stress, one must make two assumptions as follows: (1) no yielding occurs in the third direction and (2) the results of triaxial tests are directly applicable to the case of plain stress. Under these assumptions, the above derivations for plane strain also apply to the case of plane stress except that the matrix $[C^E]$ is changed to the form

$$[C^E] = \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} \tag{86}$$

This results in the following changes

$$\{q\}^T [C^E] \{q\} = \frac{2E}{1-\nu^2} [(1+\nu) \sin^2\phi + (1-\nu) (\frac{\tau_{11} - \tau_{22}}{4R})^2 + (1-\nu) (\frac{\tau_{12}}{R})^2] \quad (87)$$

$$\frac{1}{h} = \frac{2EB}{1-\nu^2} \quad (88)$$

$$B = [(1+\nu) \sin^2\phi + (1-\nu) (\frac{\tau_{11} - \tau_{22}}{4R})^2 + (1-\nu) (\frac{\tau_{12}}{R})^2] \quad (89)$$

$$\{Q\}^T = \{q\}^T [C^E]$$

$$= \frac{E}{1-\nu^2} < Q_1 \; Q_2 \; Q_3 >$$

$$= \frac{E}{1-\nu^2} < \frac{1}{2} (1+\nu) \sin\phi + (1+\nu) \frac{\tau_{11} - \tau_{22}}{4R},$$

$$\frac{1}{2} (1+\nu) \sin\phi - (1+\nu) \frac{\tau_{11} - \tau_{22}}{4R}, \; (1-\nu) \frac{\tau_{12}}{R} > \quad (90)$$

$$[C^P] = h[C^E] \{q\} \{q^T\} [C^E]$$

$$= h\{Q\} \{Q\}^T$$

$$= \frac{E}{2B(1-\nu^2)} \begin{bmatrix} Q_1^2 & Q_1Q_2 & Q_1Q_3 \\ Q_2Q_1 & Q_2^2 & Q_2Q_3 \\ Q_3Q_1 & Q_3Q_2 & Q_3^2 \end{bmatrix} \quad (91)$$

Finally, one obtains

$$[C] = [C^E] - [C^P]$$

$$= \frac{E}{1-\nu^2} \begin{bmatrix} 1 & \nu & 0 \\ \nu & 1 & 0 \\ 0 & 0 & \frac{1-\nu}{2} \end{bmatrix} - \frac{E}{2B(1+\nu)} \begin{bmatrix} Q_1^2 & Q_1Q_2 & Q_3 \\ Q_2Q_1 & Q_2^2 & Q_2Q_3 \\ Q_3Q_1 & Q_3Q_2 & Q_3^2 \end{bmatrix} \quad (92)$$

C. COLUMN ELEMENT

1. Trilinear Yield Surface of the Moment-Axial Force Interaction Diagram - Moment-axial force interaction curves for the most commonly used sections of reinforced concrete columns are available in handbooks published by the American Concrete Institute [2]. These sections include the spirally reinforced, circular and square columns, and the symmetrically reinforced, rectangular tied columns. Three typical sections are shown in Fig. 27. For other types of sections, a computer program has been developed to obtain the interaction curves by a direct analysis method [105].

There are three controlling points on the interaction curve which can be used to approximate its form using a trilinear relationship. These points are the minimum eccentricity point B, the balanced point C, and the pure moment point D, as shown in Fig. 26. Segment AB having a horizontal slope defines the ultimate axial load capacity as that axial load given by the ACI code for the minimum eccentricity condition [35]. Segment BC defining the compression failure zone connects point B with the balanced point C which corresponding to a concrete strain of 0.003 and a steel strain equal to the yield strain. Finally, segment CD connects point C with point D which corresponds to the yield moment in the presence of no axial load. This latter segment defines the tension failure zone. Since tension seldom occurs in the columns of short bridges, it is not necessary to define the interaction diagram in the negative (tension) region of P. Line segment OD therefore is considered the boundary line for the yield surface which signifies zero tension capacity.

Using the approximate trilinear form of the interaction curve, the normalized yield stress function can be written as

$$f_i (S_1, S_2) = a_i S_1 + b_i S_2 + c_i = 0 \qquad (93)$$

where

$$S_1 = \frac{P}{P^2} \quad ; \quad S_2 = \frac{M}{M^2} \qquad (94)$$

For line segments AB, BC, and CD, coefficients a_i, b_i, and c_i are, respectively,

$$\begin{array}{lll} a_1 = 1 & a_2 = \dfrac{M_1}{M_2} - 1 & a_3 = \dfrac{M_3}{M_2} - 1 \\ b_1 = 0 \quad ; & b_2 = 1 - \dfrac{P_1}{P_2} & b_3 = 1 - \dfrac{P_3}{P_2} \\ c_1 = -\dfrac{P_1}{P_2} & c_2 = \dfrac{P_1}{P_2} - \dfrac{M_1}{M_2} & c_3 = \dfrac{P_3}{P_2} - \dfrac{M_3}{M_2} \end{array} \qquad (95)$$

2. Tangent Stiffness - Using the trilinear interaction relationship, the derivation of the elastic-perfectly plastic tangent stiffness of a column follows the same procedure used previously for soils except one must consider that (1) plastic deformations are concentrated at the ends of the element with the deformations taking place independently over zero lengths at each end of the element, (2) plastic deformations are independent of the shear forces present, and (3) the stiffnesses are expressed in terms of element end forces and displacements rather than in terms of stress and strain as in the case of soil elements. In this case, one obtains

$$\{du^P\} = \begin{Bmatrix} du_I^P \\ du_J^P \end{Bmatrix} = \begin{bmatrix} \{q\}_I & \{0\} \\ \{0\} & \{q\}_J \end{bmatrix} \begin{Bmatrix} \lambda_I \\ \lambda_J \end{Bmatrix} = [q]\ \{\lambda\} \tag{96}$$

where du_I^P and du_J^P are the plastic deformation increments at ends I and J of the element, respectively, and λ_I and λ_J are the associated proportionality factors. It follows therefore that

$$\{du^P\}^T = < du_1^P \quad du_2^P \quad du_3^P \quad du_4^P \quad du_5^P \quad du_6^P > \tag{97}$$

$$\{q\}_m^T = \left\{\frac{\partial f_i}{\partial s_j}\right\}_m^T = < a_i \ 0 \ b_i >_m, \quad m = I \text{ or } J \tag{98}$$

$$\{du\} = \begin{Bmatrix} du_I \\ du_J \end{Bmatrix} = \begin{Bmatrix} du_I^E \\ du_J^E \end{Bmatrix} + \begin{Bmatrix} du_J^P \\ du_J^P \end{Bmatrix} \tag{99}$$

$$\{dS\} = \begin{Bmatrix} dS_I \\ dS_J \end{Bmatrix} = [K^E] \begin{Bmatrix} du_I^E \\ du_J^E \end{Bmatrix} \tag{100}$$

where $[K^E]$ is the elastic stiffness matrix appearing in Eq. 23. Further, one obtains

$$\{\lambda\} = \begin{Bmatrix} \lambda_I \\ \lambda_J \end{Bmatrix} = [h]\ [q]^T\ [K^E]\ \{du\} \tag{101}$$

$$[h]^{-1} = [q]^T\ [K^E]\ [q] \tag{102}$$

$$[A] = [q]\ [h]\ [q]^T\ [K^E] \tag{103}$$

$$\{dS\} = [K]\ [du] \tag{104}$$

$$[K] = [K^E] - [K^E]\,[A]$$
$$= [K^E] - [K^E]\,[q]\,[h]\,[q]^T\,[K^E]$$
$$= [K^E] - [K^P] \qquad (105)$$

3. An Approximation Used in Numerical Iteration - Due to the occurence of impact upon the frictional element at the interface of soil and abutment wall elements, the time interval used in a dynamic analysis to obtain a stable numerical solution must be quite small. It must be sufficiently small so that "overshooting" of the interaction diagram during a single interval as shown in Fig. 28 is minimized. Even though this interval is kept small, the error introduced into a solution by "overshooting' has been corrected [16, 60, 105].

In the present investigation, a simple procedure has been adopted for the overshooting. If, as shown in Fig. 28, the elastic stress state assumed during an interval moves the applied forces from point A to point B then a transition from an elastic to a yield state is indicated. While the new force vector $S_{t+\Delta t}$ as represented by point B is adopted without correction, point C which is the intersection of the new stress vector $S_{t+\Delta t}$ and the yield segment EF is used to calculate the slope of the plastic deformation vector du^P. This same procedure is used when overshooting occurs at a discontinuity point on the interaction curve as shown in Fig. 29. In this case, the elastic stress state assumed during an interval moves the applied forces from point A' to point B'. The new force vector $S_{t+\Delta t}$ intersects line EF; thus, the slope of EF is used to calculate the plastic deformation increment. Other investigators have used somewhat different procedures for this

correction [73, 77, 83, 107].

D. FRICTIONAL ELEMENT

The non-linear behavior of the frictional element is described in terms of normal and shear stiffnesses k_n and k_s during three distinct stages, namely, (1) when reparation occurs, in which case $k_n = k_s = 0$, (2) when compression occurs at the interface but the shear strength of the element is not exceeded in which case k_n and k_s are assigned high values, and (3) when compression occurs but the shear strength of the element is exceeded in which case $k_s = 0$ and k_n retains a high value. The shear yield strength of the element can be defined by the Mohr-Coulomb yield criterion, i.e.,

$$\tau = \sigma \tan \phi_w \tag{106}$$

where ϕ_w is the angle of wall friction between the soil and the abutment wall.

Before discussing the value of ϕ_w to be used, two terms must be defined [63]. Firstly, the constant volume frictional angle is defined by $\phi_{cv} = \sin^{-1} \left(\frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3} \right)_{cv}$, where σ_1 and σ_3 are the axial stress and confining pressure, respectively, in a triaxial test at that stage when the sand strains without further volume change. Secondly, peak friction angle ϕ is defined as the slope of Mohr envelope which is a function of the stresses indicated at the peak of stress-strain curve of a triaxial test.

For backfill against a concrete wall, Lamb suggests that the angle of wall friction ϕ_w is about equal to ϕ_{cv} and that it typically has a

numerical value of about 30° [63]. Seed and Whitman in a discussion of dynamically active pressure against walls suggest that $\phi_w = \phi/2$ is satisfactory for most practical purposes [97].

E. EXPANSION JOINT ELEMENT

The stiffnesses of the expansion joint element can be defined in terms of normal and shear stiffnesses k_n and k_s during three stages, (1) when the frictional resistance between the deck and abutment is not exceeded in which case k_n and k_s are assigned high values, (2) when the frictional resistance is exceeded, but the gap between deck and abutment as shown in Fig. 6a is not closed, in which case $k_s = 0$ and k_n retains a high value, (3) when the frictional resistance is exceeded and the gap is closed in which case, if the relative displacement indicated is consistent with gap closure, high values k_n and k_s are retained.

F. SOIL BOUNDARY ELEMENT AND EQUIVALENT COLUMN OF FOUNDATION

The non-linear behavior of the soil boundary element and the equivalent column foundation element can be approximated by defining yield levels using standard methods and adopting elasto-plastic hysteretic models. In the present investigation, only elastic behavior has been considered.

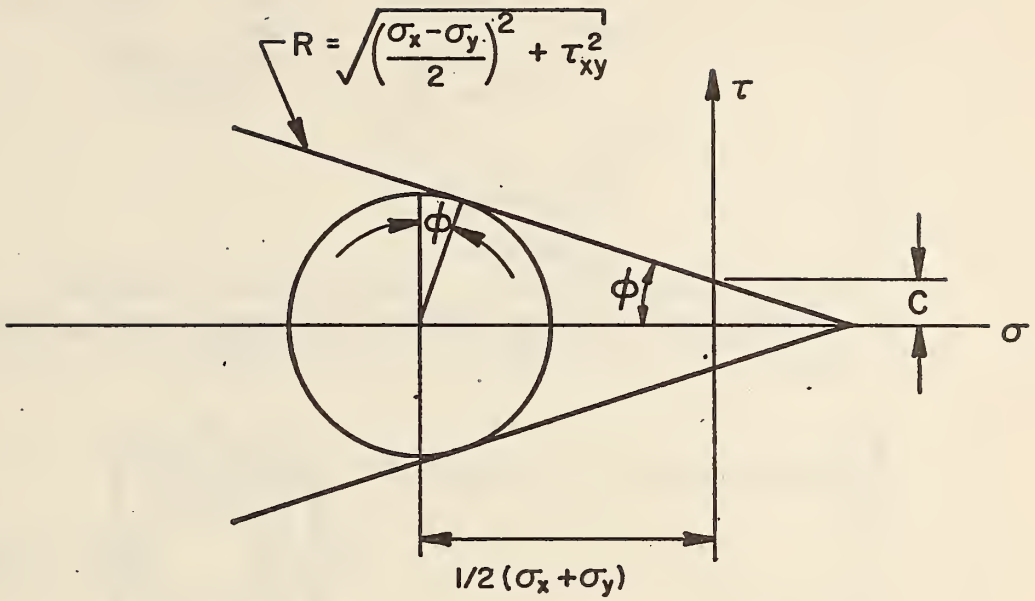


FIG. 25 MOHR-COULOMB YIELD FUNCTION

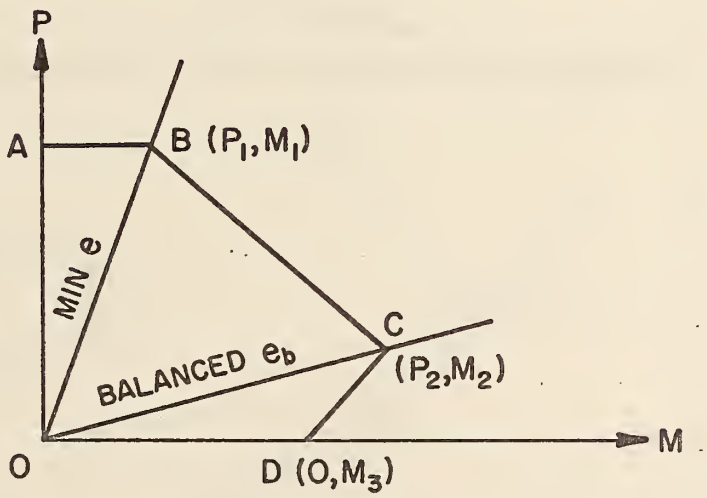
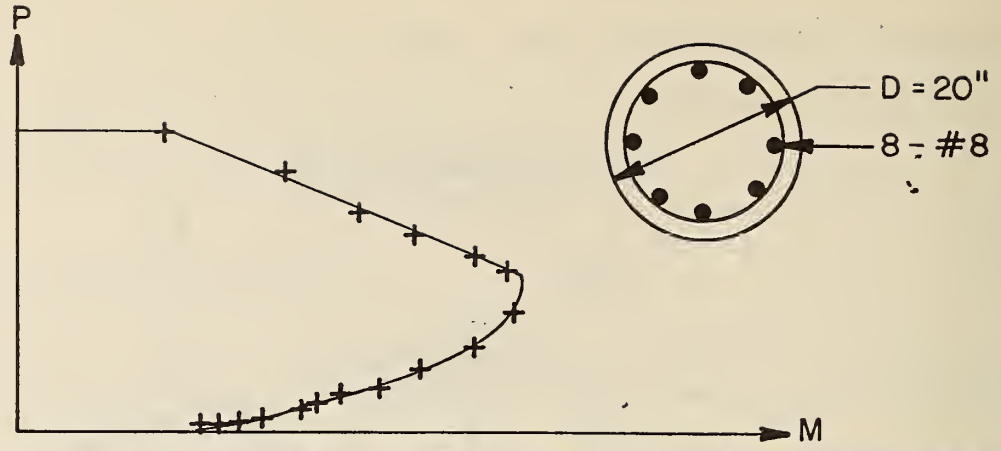
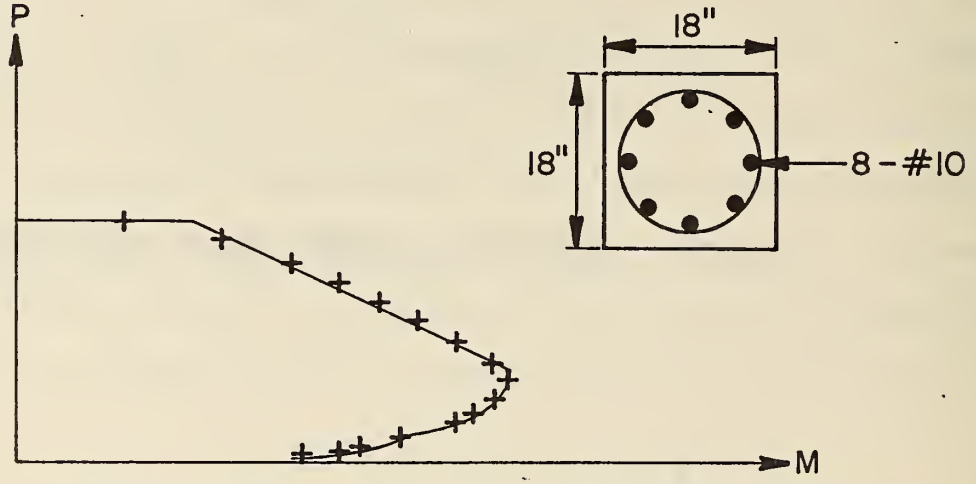


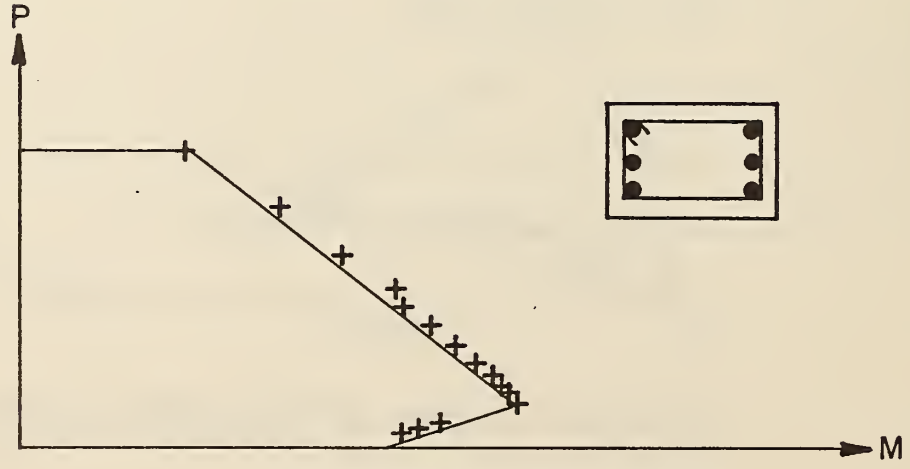
FIG. 26 COLUMN INTERACTION CURVE



(a) CIRCULAR SECTION WITH BARS CIRCULARLY ARRANGED



(b) SQUARE SECTIONS WITH BAR CIRCULARLY ARRANGED



(c) RECTANGULAR SECTION

FIG. 27 INTERACTION DIAGRAM OF CONCRETE COLUMN

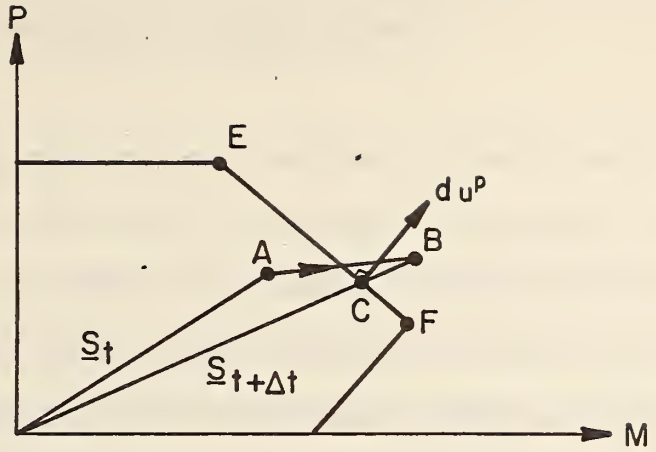


FIG. 28 SITUATION AT OVERSHOOTING

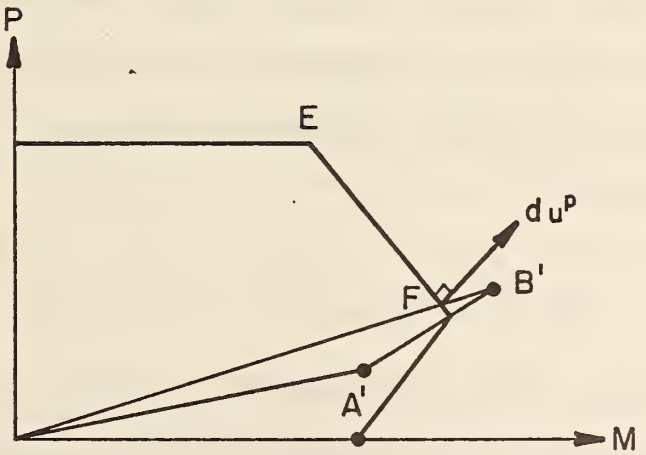


FIG. 29 OVERSHOOTING AT DISCONTINUITY

V DYNAMIC ANALYSIS PROCEDURES

In the subsequent sections, the nonlinear coupled equations of motion for the discrete parameter soil-structure system are formulated and the method used to establish their associated stiffness, mass, and damping matrices are described. Also presented are the step-by-step integration techniques employed in their solution.

A. EQUATIONS OF MOTION

Although some previous investigations have considered spacial variations in the earthquake ground motions [27, 32, 43], the present investigation assumes identical motions at all base points of the soil-structural system. This assumption is considered reasonable due to the relatively short lengths of bridges being considered.

The coupled equations of motion at time t for an N degree of freedom system subjected to rigid base excitation can be expressed in the matrix form

$$[M]\{\ddot{u}\}_t + [C]_t\{\dot{u}\} + [K]_t\{u\}_t = \{R\}_t \tag{107}$$

where [M] is the constant mass matrix, $[C]_t$, and $[K]_t$ are the time dependent damping and stiffness matrices, respectively, and where $\{u\}_t$, $\{\dot{u}\}_t$, and $\{\ddot{u}\}_t$ are the nodal point displacement, velocity, and acceleration vectors, respectively. The excitation force vector $\{R\}_t$ due to rigid base motions is given by the relation

$$\{R\}_t = - [M]\{I\}\left(\ddot{u}^x_{gt} + \ddot{u}^y_{gt}\right) \tag{108}$$

where $\{I\}$ is the unit vector and $\ddot{u}^x_{gt}$ and $\ddot{u}^y_{gt}$ are the horizontal and vertical components of ground acceleration.

B. STIFFNESS MATRIX

The complete stiffness matrix $[K]_t$ is assembled from the individual element stiffness matrices using the direct stiffness method [22]. The individual element stiffnesses during the elastic and inelastic ranges in each time interval are obtained by the procedures described in Chapters II and IV. The complete stiffness matrix takes on a symmetric banded form; thus, only the diagonal and the off-diagonal terms on one side need be stored in the computer.

C. MASS MATRIX

The mathematical model used assumes all mass as concentrated at the nodal points. The diagonal mass matrix which results represents a significant saving in computer storage and computational time when compared with similar requirements for the consistent mass matrix [21]. One-third of the mass of each triangular element, one-fourth of the mass of each quadrilateral element, and one-half of the mass of each beam element are lumped at their respective nodal points. No rotational moments of inertia are assigned to these masses. The resulting mass matrix for the complete soil-structural system takes the form

$$[M] = \text{diag} < M_1 \; M_2 \; \text{---} \; M_n > \tag{109}$$

where M_i is the mass associated with the ith degree of freedom and n

is the total number of degrees of freedom present in the system. The static condensation procedure is used to eliminate the degree of freedom of zero rotational masses in the solution of eigenvalues.

D. DAMPING MATRIX

Various methods have been used by investigators to determine the viscous damping matrix corresponding to matrix $[C]_t$ in Eq. (107) [44]. Wilson and Penzien have described two methods for evaluting orthogonal damping matrices [115]. The first method relates the modal damping ratios to the coefficients in the Caughey series form [15]. The second method is a direct approach which expresses the damping matrix as a sum of a series of matrices each of which produces damping in only one particular mode. The second approach has the advantage that prescribed damping ratios in all modes are easily controlled.

The Rayleigh damping matrix which constructs a damping matrix from a scaled linear combination of the mass and stiffness matrices is used in the present investigation. This type of damping matrix has the advantage that it can be calculated directly using the relation

$$[C]_t = \alpha[M] + \beta[K]_t \tag{110}$$

where α and β are scalar quantities to be prescribed. By properly selecting these scalar values, the damping ratios can be controlled in two normal modes. It can be shown that these quantities are related to the damping ratios (ξ) and circular frequencies (ω) of the ith and jth normal modes through the equations

$$\alpha = \frac{2\,\omega_i\omega_j\,(\xi_j\omega_i - \xi_i\omega_j)}{(\omega_i^2 - \omega_j^2)} \tag{111}$$

$$\beta = \frac{2\,(\xi_i\omega_i - \xi_j\omega_j)}{(\omega_i^2 - \omega_j^2)} \tag{112}$$

Further, it can be shown that if α and β satisfy Eqs. (111) and (112), the damping ratio in nth normal has the value given by

$$\xi_n = \frac{\alpha + \beta\ \omega_n^2}{2\,\omega_n} \tag{113}$$

In the present investigation, the numerical values of α and β are determined by using the initial elastic soil-structural system and by prescribing the damping ratios of any two modes of the system. These quantities are then held constant at these values throughout the time history of response including those periods of time when the system responds inelastically.

As shown by Eq. (107), the stiffness matrix varies with time due to nonlinear effects; therefore, the damping matrix also varies with time. Because the stiffnesses in the system decrease considerably during periods of element yielding, the viscous damping present during these periods also decreases. It should be kept in mind, however, that the major sources of energy dissipation during these periods are the hysteresis loops in the force-deformation relations as described in Chapter III.

E. STEP-BY-STEP INTEGRATION TECHNIQUES

Having the solution of the coupled equations of motion at time t, the step-by-step integration procedure allows one to obtain their solution at a later time t+Δt. To develop this procedure, the matrix equation of motion is transformed to its incremental form by subtracting Eq. (107) for time t from the corresponding equation for time t+Δt as given by

$$[M]\ (\{\ddot{u}\}_t + \{\Delta\ddot{u}\}_t) + [C]_t\ (\{\dot{u}\}_t + \{\Delta\dot{u}\}_t) + [K]_t\ (\{u\}_t + \{\Delta u\}_t)$$
$$= \{R\}_t + \{\Delta R\}_t \qquad (114)$$

In this equation, the incremental quantities represent those changes taking place during the interval Δt following time t. Thus, one obtains the incremental form

$$[M]\ \{\Delta\ddot{u}\}_t + [C]_t\ \{\Delta\dot{u}\}_t + [K]_t\ \{\Delta u\}_t = \{\Delta R\}_t \qquad (115)$$

To find the incremental changes, various procedures can be employed [7, 76]. The differences in these procedures relate to the analytical form of the variation in response over the time interval Δt. In the present investigation, two different analytical forms have been programmed for computer solution, namely, constant acceleration and linear acceleration. These forms lead to the following equations for velocity and displacement at time t+Δt expressed in terms of the state vectors at time t and the acceleration vector at time t+Δt:

Constant Acceleration

$$\{\dot{u}\}_{t+\Delta t} = \{\dot{u}\}_t + \frac{1}{2}\Delta t\ \{\ddot{u}\}_t + \frac{1}{2}\Delta t\ \{\ddot{u}\}_{t+\Delta t} \qquad (116)$$

$$\{u\}_{t+\Delta t} = \{u\}_t + \Delta t \{\dot{u}\}_t + \frac{1}{4}\Delta t^2\{\ddot{u}\}_t + \frac{1}{4}\Delta t^2\{\ddot{u}\}_{t+\Delta t} \quad (117)$$

Linear Acceleration

$$\{\dot{u}\}_{t+\Delta t} = \{\dot{u}\}_t + \frac{1}{2}\Delta t \{\ddot{u}\}_t + \frac{1}{2}\Delta t \{\ddot{u}\}_{t+\Delta t} \quad (118)$$

$$\{u\}_{t+\Delta t} = \{u\}_t + \Delta t \{\dot{u}\}_t + \frac{1}{3}\Delta t^2 \{\ddot{u}\}_t + \frac{1}{6}\Delta t^2 \{\ddot{u}\}_{t+\Delta t} \quad (119)$$

Using the following definitions for the incremental vectors

$$\{\Delta\ddot{u}\}_t = \{\ddot{u}\}_{t+\Delta t} - \{\ddot{u}\}_t \quad (120)$$

$$\{\Delta\dot{u}\}_t = \{\dot{u}\}_{t+\Delta t} - \{\dot{u}\}_t \quad (121)$$

$$\{\Delta u\}_t = \{u\}_{t+\Delta t} - \{u\}_t \quad (122)$$

the incremental velocity and acceleration vectors can be expressed in the form

Constant Acceleration

$$\{\Delta\ddot{u}\}_t = \frac{4}{\Delta t^2}\{\Delta u\}_t - \{A\}_t \quad (123)$$

$$\{\Delta\dot{u}\}_t = \frac{2}{\Delta t}\{\Delta u\}_t - \{B\}_t \quad (124)$$

where

$$\{A\}_t = \frac{4}{\Delta t}\{\dot{u}\}_t + 2\{\ddot{u}\}_t \quad (125)$$

$$\{B\}_t = 2\{\dot{u}\}_t \quad (126)$$

Linear Acceleration

$$\{\Delta\ddot{u}\}_t = \frac{6}{\Delta t^2}\{\Delta u\}_t - \{A\}_t \tag{127}$$

$$\{\Delta\dot{u}\}_t = \frac{3}{\Delta t}\{\Delta u\}_t - \{B\}_t \tag{128}$$

where

$$\{A\}_t = \frac{6}{\Delta t}\{\dot{u}\}_t + 3\{\ddot{u}\}_t \tag{129}$$

$$\{B\}_t = 3\{\dot{u}\}_t + \frac{1}{2}\Delta t\{\ddot{u}\}_t \tag{130}$$

Using these relations, the incremental equation of motion, Eq. (115), can be written in the form

$$[\bar{K}]_t\{\Delta\bar{u}\}_t = \{\Delta\bar{R}\}_t \tag{131}$$

where

$$\{\Delta\bar{R}\}_t = \{\Delta R\}_t + [M]\{A\}_t + C_2[M]\{B\}_t \tag{132}$$

$$[\bar{K}]_t = [K]_t + C_1[M] \tag{133}$$

and the actual incremental displacement vector can be expressed as

$$\{\Delta u\}_t = C_3(\{\Delta\bar{u}\}_t + \beta\{B\}_t) \tag{134}$$

Constants C_1, C_2, and C_3 are given by the relations

Constant Acceleration

$$C_1 = \frac{2\alpha\Delta t + 4}{\Delta t^2 + 2\beta\Delta t} \tag{135}$$

$$C_2 = \alpha - C_1\beta \tag{136}$$

$$C_3 = \frac{\Delta t}{\Delta t + 2\beta} \tag{137}$$

Linear Acceleration

$$C_1 = \frac{3\,\alpha\,\Delta t + 6}{\Delta t^2 + 3\,\beta\,\Delta t} \tag{138}$$

$$C_2 = \alpha - C_1\,\beta \tag{139}$$

$$C_3 = \frac{\Delta t}{\Delta t + 3\beta} \tag{140}$$

After computing the incremental displacement vector using Eq. (134), the corresponding incremental acceleration and velocity vectors are determined using Eqs. (123) and (124), or Eqs. (127) and (128), respectively. The displacement, velocity and acceleration vectors at time $t+\Delta t$ are then evaluated using Eqs. (120), (121) and (122), respectively. The tangent stiffness, strain, and stress for each element can now be calculated for time $t+\Delta t$.

An alternative solution of the incremental equilibrium equation, Eq. (115) can be obtained by separating the tangent stiffness matrix $[K]_t$ into its elastic and plastic parts, $[K^E]$ and $[K^P]_t$, as described in Chapter IV. That term associated with plastic deformation is then transferred to the right hand side of the equation of motion and is treated as an equivalent load vector [21].

In the above described step-by-step integration procedures, the initial displacements and velocities at time t = 0 are assumed equal to zero. The very first incremental acceleration vector is then computed directly from Eq. (115), i.e.,

$$[M]\,\{\Delta\ddot{u}\}_0 + [C]_0\{0\}_0 + [K]_0\,\{0\}_0 = \{\Delta R\}_0$$

or

$$\{\Delta\ddot{u}\}_0 = [M]^{-1} \{\Delta R\}_0 = [M]^{-1} \{R\}_0 = -\{\ddot{u}_g\}_0$$

The initial forces existing in the elements cannot be assumed zero but must be taken equal to the static gravitational forces since tangent stiffness is dependent upon total force (gravity plus seismic).

While step-by-step integration procedures similar to those described above must be used for nonlinear analyses, they may or may not be used for linear analyses since the mode superposition method is an alternate method which can be used for linear analyses [116]. In the present investigation, it was found computationally convenient to use the step-by-step method for both linear and nonlinear analyses.

F. TIME INTERVAL Δt

The step-by-step integration method is accurate only if the time interval Δt is small compared with the shortest period T of the soil-structural system and is also small compared with the predominant periods in the excitation. Assuming the latter condition is satisfied, the ratio $\Delta t/T$ must be selected less than a certain critical value to insure a convergent and stable solution in the case of the linear acceleration method; however, it can be shown that the constant acceleration method is always stable for a linear system [76]. In the present study, the presence of the nonlinear friction elements tend to encourage an unstable response, if the $\Delta t/T$ ratio is taken too large. Therefore, extreme care must be taken in selecting the numerical value of this ratio. The effects of this particular parameter on dynamic response are discussed

subsequently in Chapter VI.

G. EARTHQUAKE INPUT

In the present investigation, the horizontal ground motion was prescribed in accordance with the acceleration time-history shown in Fig. 30. This artificial accelerogram was generated by A. K. Chopra to simulate the ground motions produced by the San Fernando earthquake at the site of the Olive View Hospital located about 6 miles southwest of the epicenter [18]. It has a peak acceleration of 0.5 g and a uniform phase of high intensity shaking for 8 seconds.

The vertical ground motions were assumed zero for the present study, but the computer program has the option to permit input of vertical ground motions.

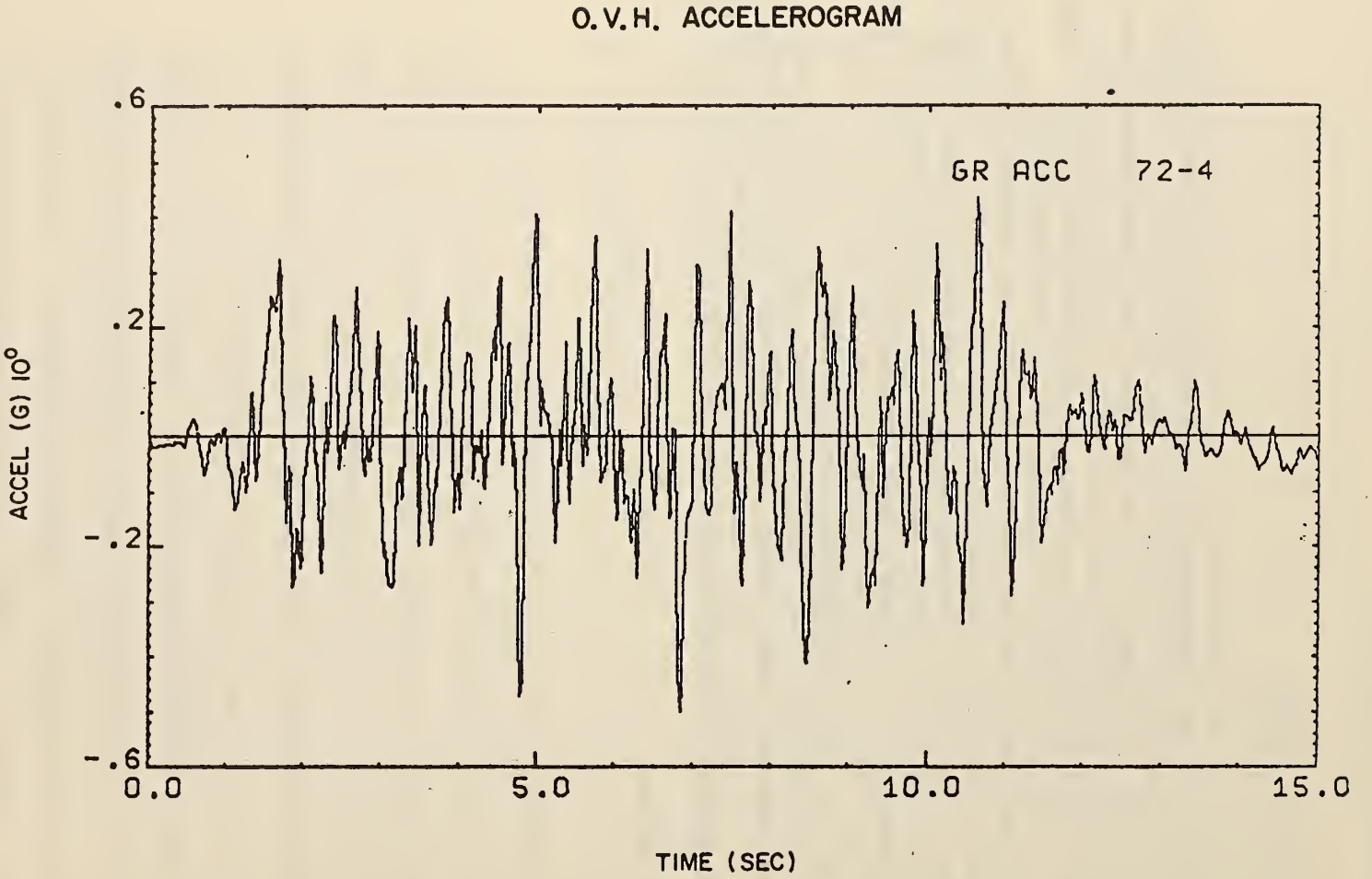


FIG.30 SIMULATED GROUND ACCELERATION RECORD OF THE SAN FERNANDO EARTHQUAKE AT THE OLIVE VIEW HOSPITAL SITE

VI PARAMETER STUDIES

The previously defined mathematical modelling and dynamic analysis procedures have been applied to a straight version of an existing slightly-curved skewed bridge, namely, the North Connector Undercrossing located approximately 800 ft. northerly of Route 5 - San Fernando Road Interchange in the city and county of Los Angeles. Plan and elvation views of this bridge are shown in Fig. 31 along with cross-sectional views of the decks and the centrally located supporting columns. Figure 32 shows a sectional view of the left abutment with a portion of the backfill of extent L and height H.

It is the purpose of this chapter to present the results of dynamic analyses for the North Connector Undercrossing when subjected to one component of earthquake excitation in its longitudinal direction. The ground motions used in this study were the Olive View Hospital accelerations shown in Fig. 30 during the time interval 2-4 seconds. This relatively short duration was chosen to minimize computer time and yet to provide sufficient time for a representative dynamic response to occur. The peak acceleration in this excitation is approximately 0.3 g.

In order to establish an appropriate mathematical model of the entire bridge-soil system, parameter studies were first carried out using a rigid wall with uniform elastic backfill. The complete bridge-soil system was then analyzed with certain parameter variations. The results of these studies along with the results of an integration-time-interval sensitivity analysis are presented in the subsequent sections of this chapter.

A. RIGID WALL-BACKFILL SYSTEM

1. Lateral Extent of Backfills - To study the longitudinal dimension or extent of backfill required in the mathematical modelling of bridge-soil systems, analyses were conducted using a single rigid wall and a uniform linear-elastic backfill having the properties γ = 110 pcf, ν = 0.35, and G = 10 ksi. Five cases with L/H ratios equal to 4.8, 6.0, 10.0, 14.0, and 22.0, as shown in Fig. 33, were used in this investigation. The finite element idealization consists of 5 elements in the vertical direction and a variable number in the horizontal direction. The element length to height ratio R = a/b was maintained at a constant value equal to 2 throughout the extent of the backfill in Cases 1 and 2 but was maintained only over a distance 2H from the wall in Cases 3, 4, and 5. This ratio was set equal to 4 for all elements beyond the distance 2H in the latter cases. No friction elements were placed between the rigid wall and the backfill in these particular studies and the left vertical boundary of the backfill was assumed free in each case. The fundamental period of the soil system under these conditions is about 0.08 seconds in each case with slight increases occurring with increasing values of L/H as shown in Table 1.

Assuming rigid body earthquake excitations to occur along the entire base of the backfill and at the rigid-wall vertical-boundary and assuming 5 percent of critical damping in the first two modes of vibration, time histories of response were obtained for all 5 cases. Response quantities of greatest interest were the maximum or peak values of (1) total lateral dynamic force exerted on the rigid wall, and (2) horizontal displacements and accelerations at various location in the backfill.

Figure 34 shows the maximum total lateral dynamic force F_d exerted on the wall for each of the 5 cases studied. This force is reasonably constant at a value of approximately 14.5 kips over the range studied; i.e. $4.8 < L/H < 22$, and is about 3.9 times greater than the average static value which is approximately 3.7 kips. The mean location of the resultant force F_d was found to be at a distance 0.52 H above the base which is considerably higher than the position of the resultant static force F_s located at 0.34 H.

The maximum horizontal displacements relative to the moving base at 6 different locations in the backfill are shown in Fig. 35 for all 5 cases. While these displacements are reasonably constant over the range of L/H studied, large differences are noted from one point to another. The displacements for points 1 and 2 are very small due to the fact they are located only one element away from the rigid wall. Points 3 and 4 which are 5 elements away from the wall experienced much larger displacements than points 1 and 2 and points 5 and 6 at the left boundary experienced even larger displacements. These relative displacements reflect the manner in which the rigid wall boundary effects decay with increasing distance from the wall. The displacements for points 3 and 5 are considerably larger than the corresponding displacements for points 4 and 6, respectively; thus, demonstrating the increase in displacements with vertical distance above the rigid base.

Figure 36 shows the maximum total horizontal acceleration at locations 1-6 for all 5 cases studied. The relative variations of this response quantity with L/H, horizontal distance from the wall, and vertical distance above the base are similar to those previously described

for horizontal displacement. It should be noted that the average acceleration with L/H ranges from about 0.5 g for points 1 and 2 to about 1.1 g for point 5. These values represent a rather small amplification of acceleration at points 1 and 2 and a fairly large amplification of the acceleration at point 5 over the peak excitation acceleration of about 0.3 g.

Based on the numerical results shown in Figs. 34-36 and summarized in Table 2, it appears that an L/H ratio equal to 14 is sufficient for use in any bridge-soil analysis. This ratio may even be reduced to a value of 6 with little loss in accuracy in determining the maximum values of abutment backfill forces. However, this reduction could introduce significant changes in the predicted maximum horizontal accelerations.

2. Length to Height Ratio of Finite Elements - Length to height ratios R = a/b for the finite elements of the backfill model were rather arbitrarily assigned values as shown in Table 1 for the 5 cases previously defined. To investigate the influence of changing these ratios, 4 new cases as shown in Fig. 37, each having an L/H ratio equal to 10, are defined. The length to height ratio equals 2 throughout the model for Case 1 and over a distance 2H from the wall for Cases 2, 3, and 4. Beyond 2H, the length to height ratio equals 4, 6, and 10 for Cases 2, 3, and 4, respectively. Five elements are again used in the vertical direction of the model and fixed and free boundaries are prescribed at the right and left ends, respectively. Linear elastic soil properties are again assumed equal to the values previously assigned.

As before, rigid body earthquake excitations are assumed to occur along the entire base of the backfill and 5 percent of critical damping

is assigned to the first two modes of vibration. Time histories of response are obtained for all 4 cases, including (1) total dynamic force exerted on the rigid wall, and (2) horizontal displacements and accelerations at 6 locations in the backfill.

Figure 38 shows total static force F_s and the maximum total dynamic lateral force F_d exerted on the wall for each of the 4 cases defined above. This force is fairly constant at a value of approximately 14.5 kips over the range of R assigned beyond x = 2H and is about 3.9 times greater than the average static value. The mean location of the resultant force F_d is at a distance about 0.52H above the base. The average position of the static resultant is 0.34H.

The maximum horizontal displacements relative to the moving base and the maximum total horizontal accelerations at the 6 different locations are shown in Figs. 39 and 40, respectively, for all 4 cases. The results in these figures are quite similar to the results shown the corresponding Figs. 35 and 36. Thus, it is apparent that the changes introduced in R for x > 2H have introduced relatively small changes in overall response and that Case 4, Fig. 37, can be considered a reasonable model of the backfill.

Table 3 presents a summary of maximum response for the above described 4 cases.

3. Number of Finite Elements in the Vertical Direction - All previous cases analyzed have used 5 finite elements in the vertical direction of the backfill. To check the adequacy of this number the distributions and resultant magnitudes of the static and dynamic backfill pressures on the rigid retaining wall are compared using 5 and 10 elements

in this direction.

Two cases as defined in Fig. 41 are used for this comparison. Both cases use an L/H ratio equal to 10 and R ratios equal to 2 and 10 for $x < 2H$ and $x > 2H$, respectively. Case 1 uses 5 elements in the vertical direction while Case 2 uses 10 elements.

It is quite clear from the results in Fig. 41 that the distributions and maximum resultant magnitudes of the backfill forces are very similar for Cases 1 and 2 and that the positions of the corresponding resultants almost coincide. Considering this fact and the fact that their time histories (see Fig. 42) are very similar, one may conclude that 5 finite elements in the vertical direction of the backfill is sufficient for engineering purposes.

4. Soil Stiffness - To study the influence of soil stiffness on the dynamic response of the backfill soil system, the finite element model identified as Case 4 in Fig. 37 was analyzed for three soil conditions, namely, a uniform soil modulus equal 10 ksi, a uniform soil modulus equal to 2.5 ksi, and a variable soil modulus in accordance with Eq. (38) for $K_2 = 50$. Poisson's ratio ν was assumed equal to 0.35 and the unit weight was again assigned the value 110 pcf. These new soil conditions are identified as Cases 1 - 3 in Fig. 43.

While the shapes of the distributions of maximum total wall pressures and their resultant force positions are quite similar for all three cases, the magnitudes of the resultant dynamic wall pressures vary considerably with the soil stiffness condition. This variation ranges from $F_d = (100)(13.06)$ for Case 3 to $F_d = (154.0)(13.06)$ for Case 2. Obviously, for the particular excitation used, the less stiff backfill soils produce

higher backfill forces on the rigid wall. If an excitation having a different amplitude distribution with frequency had been used, this observation could be changed considerably. Therefore, one must use caution in interpreting the results of this particular study. It is important to recognize however that soil stiffness can be an important parameter which should be studied using realistic earthquake excitations.

5. Frictional Element Stiffnesses - As pointed out previously, the shear and normal stiffnesses of the frictional elements located between backfill soil and abutment walls are arbitrarily assigned finite but very high values rather than infinite values to avoid discontinuities in their force displacement relations. To study the influences of these stiffnesses on dynamic response, the rigid wall-soil system shown in Fig. 44 was analyzed assuming linear soil behavior. In these studies the shear and normal stiffnesses (K_S and K_N) for each frictional element were assigned equal values ranging from 1 to 10^9 ksi.

The total static and total maximum dynamic lateral wall forces (F_s and F_d) obtained in these studies are plotted in Fig. 45 for stiffnesses $K_S = K_N$ equal to 1, 10^3, 10^6, and 10^9 ksi. As one would expect, these forces are reasonably constant over a wide range of stiffnesses. However, as the stiffnesses approach zero, F_s and F_d also approach zero which represent unrealistic values. Theoretically both F_s and F_d should approach constant values asymptotically with increasing stiffnesses, however the value of F_d for $K_S = K_N = 10^9$ ksi is much larger than for the smaller values of stiffness. This large increase is due to a numerical instability which developed in the analysis procedures and therefore

should be ignored. It appears therefore that realistic wall forces can be obtained by selecting stiffnesses in the range $10^3 < K_S = K_N < 10^6$ ksi.

Although the asymptotic static value of wall force in Fig. 45 is consistent with values previously presented for cases having no friction elements, the maximum dynamic force of about 40.0 kips is considerably larger than the average value (14.5) previously presented. This increase in dynamic wall force is due to the separations and associated impacts which occur between the backfill soil and the upper part of the rigid wall. Thus it appears that for high intensity excitations, the friction element is essential to realistic modelling.

B. INTEGRATION-TIME-INTERVAL SENSITIVITY ANALYSIS

Throughout the rigid wall-backfill parameter studies previously described, the numerical integration time step was assigned a value equal to 0.01 seconds and the constant acceleration method was used which enables response to be stable, but not necessarily convergent, for all modes of vibration. To study the adequacy of using 0.01 seconds for Δt, the rigid wall-soil system defined by Case 4, Fig. 37, was re-analyzed using $\Delta t = 0.001$ seconds. The total number of degrees of freedom for this system is 90 with the fundamental period being 0.084 seconds and the highest period estimated at 0.0065 seconds. The convergent limit of the ratio of time step duration to period, i.e. $\Delta t/T$, is 0.39 for the constant acceleration method. Thus, for $\Delta t = 0.01$ seconds, the convergent period T is 0.026 seconds. Since this period corresponds to the period of the 22nd mode of vibration, only the lowest 22 modes are

convergent in the constant acceleration method of analysis when $\Delta t = 0.01$ seconds. If on the other hand, $\Delta t = 0.001$ seconds, all modes are convergent.

To check the accuracy of response obtained for the above case using $\Delta t = 0.01$ seconds, the time histories of lateral dynamic wall force and horizontal acceleration at point No. 1 (see Fig. 40) are obtained for $\Delta t = 0.001$ and are plotted in Fig. 46 where they can be compared with corresponding results for $\Delta t = 0.01$ seconds. The vertical acceleration time histories for point No. 1 are plotted in Fig. 47 for $\Delta t = 0.01$ and 0.001 seconds. A summary of the maximum values of response for this case is presented in Table 4.

Obviously, the results of Fig. 46 indicate that a time step interval of 0.01 seconds is quite adequate in predicting total lateral wall force and horizontal acceleration time histories. However, the results of Fig. 47 indicate the very low level vertical acceleration time histories caused primarily by very high frequency modal responses cannot be predicted accurately by $\Delta t = 0.01$ seconds. Since this high frequency response is relatively unimportant from an engineering point of view, it is concluded that $\Delta t = 0.01$ seconds is adequate for the previously described rigid wall-soil parameter studies and also for the bridge-soil system studies to be described subsequently.

C. BRIDGE-SOIL SYSTEM

To study the dynamic response of the combined bridge-soil system, 3 mathematical models of the North Connector Undercrossing as shown in Fig. 48 were defined. Model A has fixed boundary conditions at depth H

of the backfills, at the base of abutments, and at the base of all columns. Model B has fixed boundary conditions at depths 2.2H and 2.5H of the backfills, leveling with bases of pier columns, which allows the base of abutments to translate and rotate with the soil system, and fixed boundary conditions are also provided at the base of all columns. Model C has fixed boundary conditions only along the base of the backfills as in Model B. The bases of abutments and columns of this model are attached to equivalent columns representing the foundation flexibility. These equivalent columns of course, have fixed boundary conditions at their bases.

The soil elements in all three models can be assumed linear or nonlinear as desired and friction elements can be included in Models A and C, but not in Model B. The backfills extend a distance 6H in all models as shown. The bridge deck is linear in each model; however, either linear or nonlinear columns can be used. Backfill and foundation soils were assumed to have the properties G = 10.0 ksi, ν = 0.35, γ = 110 lb/ft^3, c = 0, and ϕ = 30°.

1. Soil Pressures on Abutments - The static and maximum dynamic pressure distributions on one abutment wall for two cases are shown in Fig. 49. The model used for Case 1 is Model A with no friction elements and with all other elements assumed linear. The model used for Case 2 is Model B in its complete linear form. Due to the characteristic response of the bridge-soil system, the static and dynamic pressure distributions are quite different in form in each case. The resultant lateral static force F_s for Case 2 is about 17% less than for Case 1, due to the change in abutment flexibility and the maximum resultant

dynamic force F_d for Case 2 exceeds the value for Case 1 by 170%. This latter difference is undoubtedly due to a closer matching of the lower mode periods of vibration for Case 2 with the predominant periods in the excitation. The location of the resultant static force is at about H/3 for Case 1 and at about H/2 for Case 2 while the location of the maximum dynamic resultant force is at about 0.53H and 0.6H, respectively.

Another check on the influence of bridge structure flexibility on the resultant abutment soil forces can be made by comparing the results for Cases 1 and 2 in Fig. 50. In this figure, Case 1 is identical to Case 1 in Fig. 49 but Case 2 is different. Here, Case 2 is actually the same as Case 1 except that the abutment wall and column stiffnesses have been reduced by a factor of 10. It is seen that Case 2 shows a 75% increase in the maximum dynamic resultant force over Case 1 due to the decrease in bridge structure flexibility. This increase is consistent with the similar increase previously noted for Case 2 in Fig. 49. The location of the resultant dynamic lateral force is again at about mid-height. The increase in the resultant static force for Case 2 over the value for Case 1 is due to the increase in rotation (due to deck dead loads) at the top of the abutment caused by the reduced abutment flexibility.

Further results of analysis are shown in Fig. 51 identified as Cases 1, 2, and 3. In this figure, Case 1 is again the complete linear version of Model A. Cases 2 and 3 are also based on Model A but Case 2 has introduced one nonlinearity, namely the friction elements, and Case 3 has employed two nonlinearities - friction elements and nonlinear soil elements. The very large increase in maximum dynamic force F_d for

Cases 2 and 3 over Case 1 is due primarily to the impact wall forces following separations between wall and backfill.

Finally the results of two additional analyses are shown in Figure 52. Cases 1 and 2 in this figure are based on Model C using friction elements and linear soil elements; however, Case 2 uses the equivalent foundation columns while Case 1 does not. The most significant result to note in Fig. 52 is that force F_d is more than twice as great for Case 2 over the value shown for Case 1. Again this increase is due to the fact that the more flexible bridge system has a closer matching of frequencies with the predominant frequencies in the excitation.

2. Total Seismic Force Carried by Columns and Abutments - To investigate the maximum total base shear carried by columns and abutments, five cases were analyzed as indicated in Table 5. Case 1 represents the bridge alone with no soil-structure interaction, i.e. Model A, Fig. 48, but with no backfill; Case 2 is Model A with linear backfill and no friction elements; Case 3 is Model B, Fig. 48, with linear backfill; Case 4 is Model A with linear backfill and friction elements; and Case 5 is Model A with non-linear backfill and friction elements. Clearly, the presence of backfill contributes significantly to the maximum total base shear, also it appears from Case 3 that the total base shear increases with overall flexibility which is again evidence of a better matching of the lower natural frequencies with the predominant frequencies in the excitation. The relatively large displacement shown for Case 3 is due to the large flexibility of the system for this case in comparison with the other cases.

D. COMPARISON OF RESULTANT ABUTMENT BACKFILL FORCE OBTAINED BY ANALYSIS AND THE MONONOBE-OKABE METHOD

One commonly used formula in calculating the resultant dynamic lateral force on the abutment wall is the Mononobe-Okabe formula [53, 55, 97]. This formula has the following form

$$P_p = (1-K_v) \cdot r \cdot x \cdot K_{Ep} \tag{141}$$

where

P_p = Passive earthpressure at depth x

K_v = vertical seismic coefficient

γ = Unit weight of soil

x = arbitrary depth

K_{EP} = Passive earthpressure coefficient during earthquake

The coefficient K_{Ep} is given by

$$K_{Ep} = \frac{\cos^2(\phi-\theta_0+\theta)}{\cos\theta_0 \cdot \cos\theta^2 \cdot \cos(\theta-\theta_0)\left[1-\sqrt{\frac{\sin\phi \cdot \sin(\phi+\alpha-\theta_0)}{\cos(\theta-\theta_0)\cdot\cos(\theta-\alpha)}}\right]^2} \tag{142}$$

where

ϕ = Angle of friction of soil

$\theta_0 = \tan^{-1}\frac{K_h}{1-K_v}$

K_h = Horizontal seismic coefficient

θ = Angle between the backline of the wall and the vertical line

α = Angle between ground surface and the horizontal line

Using $\phi = 30°$; $\theta = 0°$; $\theta_0 = \tan^{-1} \frac{0.1}{1-0.0} = 6°$; $\alpha = 0°$; $\gamma = 110$ lb/ft^3

$$K_{Ep} = 2.86$$

The earthpressure at bottom of wall is

$$p_p = (1-0.0) * 110 * 13.5 * 2.86 = 4.25 \text{ K/ft}^2$$

and the total lateral force on the wall is

$$F_d = \frac{1}{2} * 13.5 * 4.25 = 28.6 \text{ K/ft}$$

Using the non-linear form of Model A, Fig. 48, or Case 3 of Fig. 51, analysis gives

$$F_d = 35.0 \text{ K/ft}$$

This analytical result is a higher value than that formula given by the Monobe-Okabe. The position of the resultant force is assumed a distance H/3 above the base when using the formula; however, the analysis shows it to be 0.44H above the base. This higher position given by an analysis is consistent with other investigations [97, 117].

Table 1 Details of Rigid Wall Systems for Study of Lateral Extent

Case	L/H	Subdivision of System	Fundamental Period (Sec.)	
1	4.8	R=2 Uniformly	0.0825	1. Time step for all cases is 0.01 sec. 2. Damping ratio is 0.05 for first two modes 3. G = 10.0 ksi
2	6.0	R=2 Uniformly	0.0838	
3	10.0	R=2 for x < 2H R=4 for x > 2H	0.0846	
4	14.0	R=2 for x < 2H R=4 for x > 2H	0.0848	
5	22.0	R=2 for x < 2H R=4 for x > 2H	0.0849	

Table 2 Comparison of Responses of Rigid Wall System at Different Lateral Extent, Using Case 5 as a Basis for Calculating the Percentage

Case	F_s	F_d	A_1	A_2	A_3	A_4	A_5	A_6	U_1	U_2	U_3	U_4	U_5	U_6
	%													
1	99.1	105.8	100.3	98.9	124.4	116.8	97.4	96.2	115.2	104.1	115.9	115.1	98.4	97.6
2	99.1	103.3	100.2	100.1	115.8	110.2	106.8	103.1	108.9	102.5	110.5	109.7	107.3	104.7
3	100	99.4	98.9	99.5	102.3	99.5	117.3	113.2	99.1	99.2	94.8	96.7	113.5	110.9
4	100	97.9	97.9	98.9	104.5	99.0	98.8	100.3	98.2	97.5	99.4	99.3	100.3	100.2
5	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Case 5 in Absolute Value	Kips		$in/sec^2 \times 10^2$						$in \times 10^{-2}$					
	3.73	14.54	1.90	1.88	2.21	1.96	4.23	2.87	1.12	1.21	4.65	2.99	8.75	5.31

1. A_i and U_i are the Maximum Acceleration and Displacement at point i respectively

2. F_s and F_d are the Static and Maximum Dynamical Lateral Forces.

Table 3 Comparison of Responses of Rigid Wall System With Different Length to Height Ratio R = a/b, Using Case 1 as Basis for Calculating the Percentage

Case	F_s	F_d	A_1	A_2	A_3	A_4	A_5	A_6	U_1	U_2	U_3	U_4	U_5	U_6
	%													
1	100	100	100	100	100	100	100	100	100	100	100	100	100	100
2	100	98.8	98.9	99.5	99.6	97.0	97.3	100	97.4	99.2	97.6	97.6	95.8	97.4
3	100	99.0	98.4	98.9	97.4	93.0	92.2	97.2	94.7	97.5	95.1	94.3	89.7	93.1
4	100	98.6	98.4	99.5	99.1	96.0	75.9	87.4	97.4	99.2	100.4	99.0	75.0	80.5
Case 1 in Absolute Value	Kips		$in/sec^2 \times 10^2$						INCH $\times 10^{-2}$					
	3.73	14.63	1.90	1.88	2.27	2.01	5.10	3.25	1.14	1.21	4.52	2.96	10.36	6.05

1. A_i and U_i are the maximum acceleration and displacement at point i respectively

2. F_s and F_d are the static and maximum dynamical lateral force

3. Refer to Fig. 37 for details of subdivision

Table 4 Comparison of Responses of Rigid Wall System With R = 2 for x < 2H and R = 10 for x > 2H at Different Time Step. Using Case 2 as basis

Case	Time Step	F_s	F_d	A_{1h}	A_{1v}	A_{2h}	A_{2v}	A_{3h}	A_{3v}
	Sec	%							
1	0.01	100	99.0	96.4	233.3	96.0	109.0	95.3	82.1
2	0.001	100	100	100	100	100	100	100	100
Case 2 in Absolute Value	Sec	Kips		$in/sec^2 \times 10^2$					
	0.001	3.725	14.58	1.94	0.056	2.01	0.041	2.98	0.51

1. F_s, F_d are the static and maximum dynamical lateral forces

2. A_{ih}, A_{iv} are the maximum horizontal and vertical acceleration at point i.

Table 5 Comparison of Maximum Total Seismic Force on the Bridge With or Without Soil Interaction

Case	Bridge Model	A_x	U_x	F_{max}	Remarks
		%			
1	Bridge alone	100	100	100	1. F_{max} is the maximum total seismic force on the bridge 2. A_x, U_x is the horizontal acceleration and displacement at the center of deck at the time of F_{max} 3. Case 2 - Fig. 48-A, no friction element Case 3 - Fig. 48-B Case 4, 5 - Fig. 48-A, with friction element
2	linear bridge-soil system, abutment base fixed	73	140	168	
3	linear bridge-soil system, abutment on soil	237	1120	205	
4	Bridge-soil system, linear soil, non-linear friction	138	186	276	
5	Bridge-soil system, non-linear soil and friction	163	151	225	
Case 1 Absolute Value		g's	INCH 10^{-2}	KIPS	
		0.50	3.63	408.0	

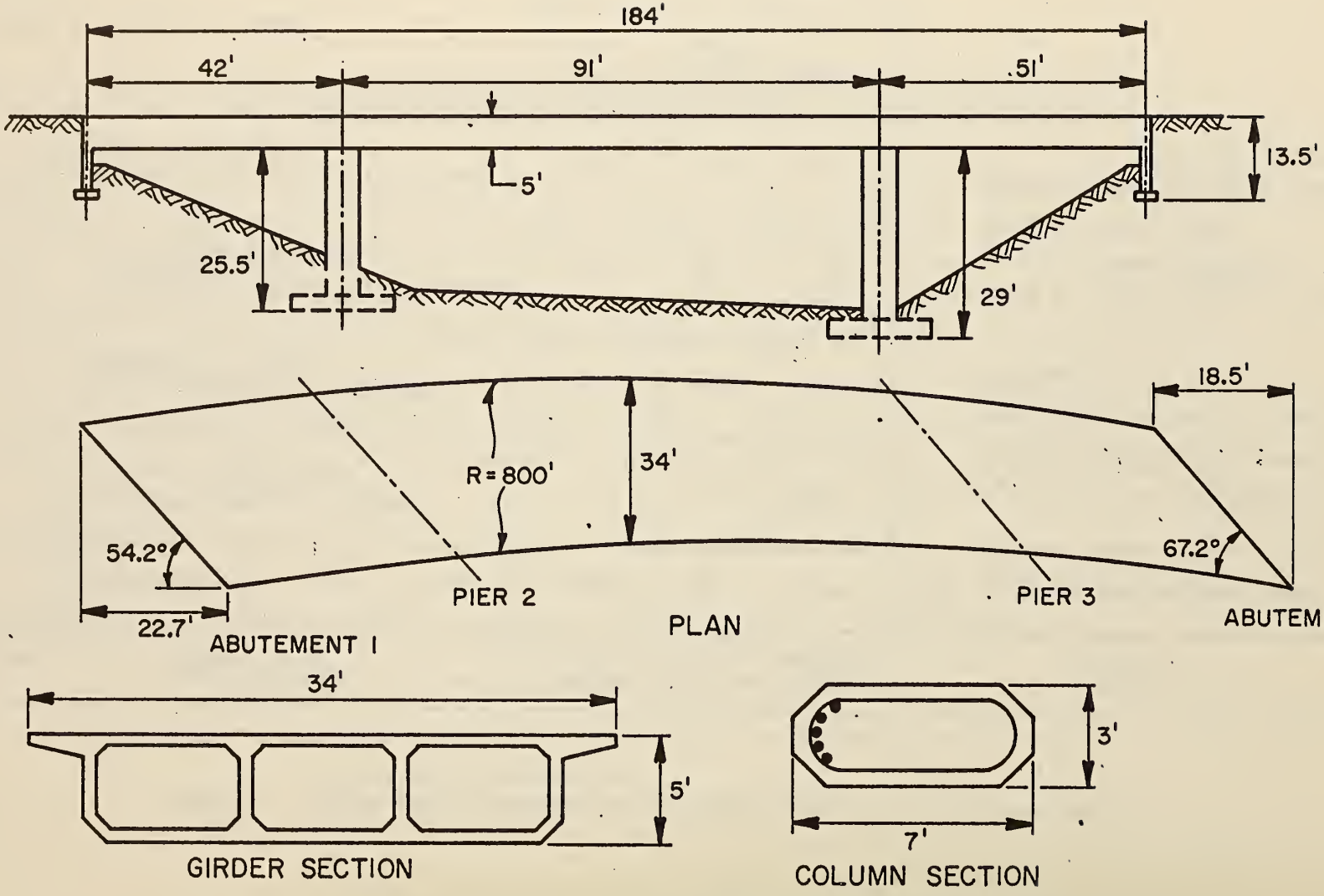


FIG. 31 GENERAL PLAN OF NORTH CONNECTOR UNDERCROSSING

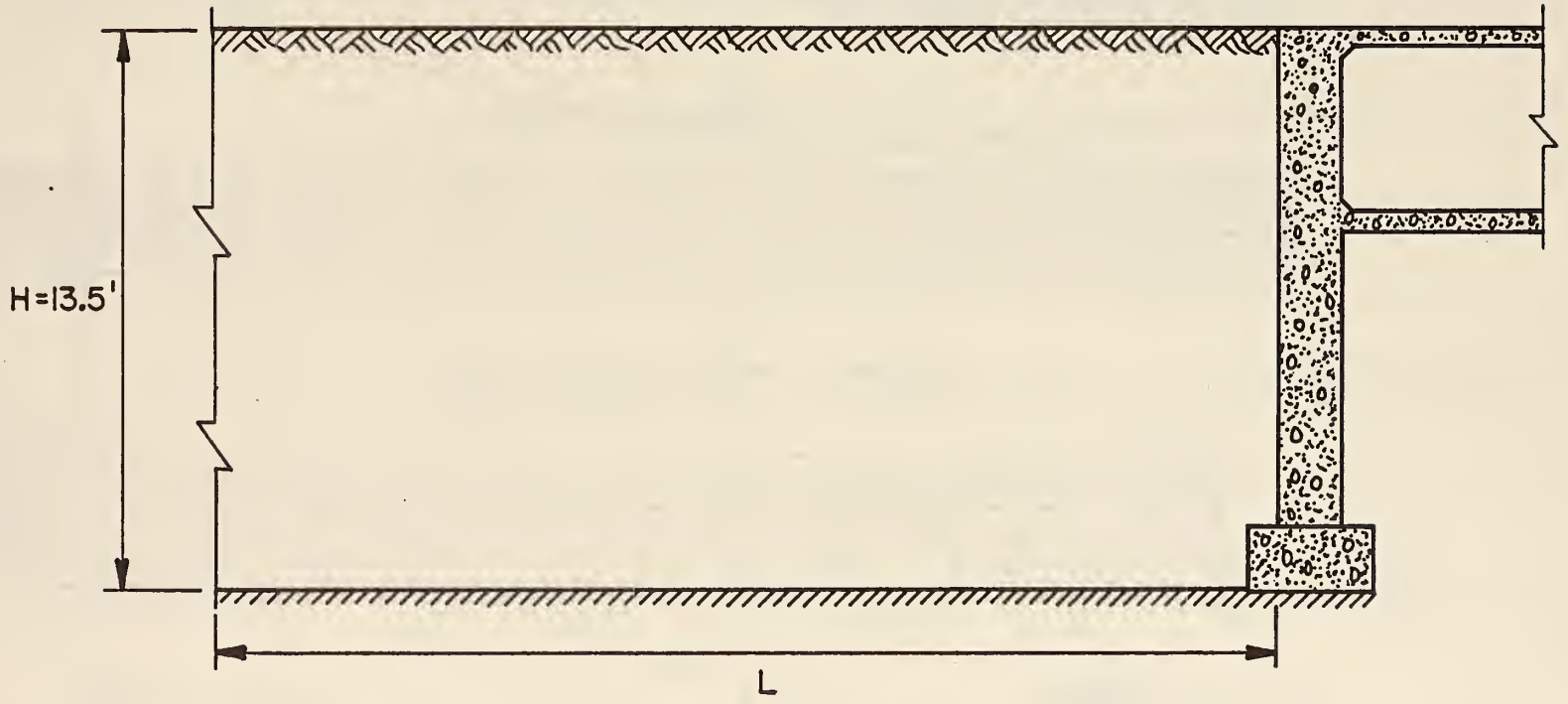
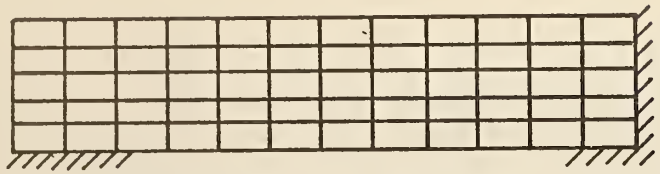
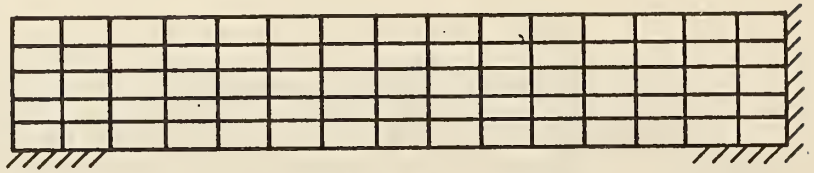


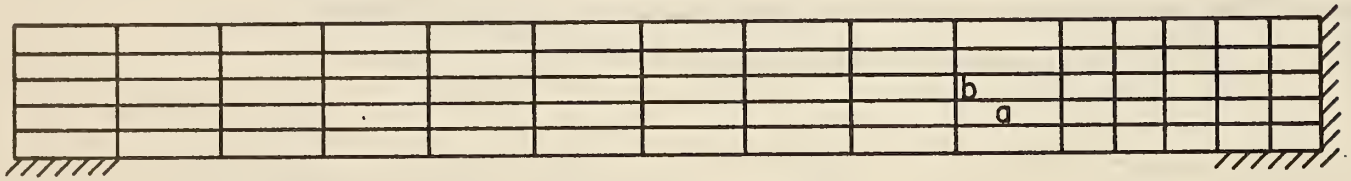
FIG. 32 ABUTMENT AND BACKFILLS



CASE 1 L/H = 4.8

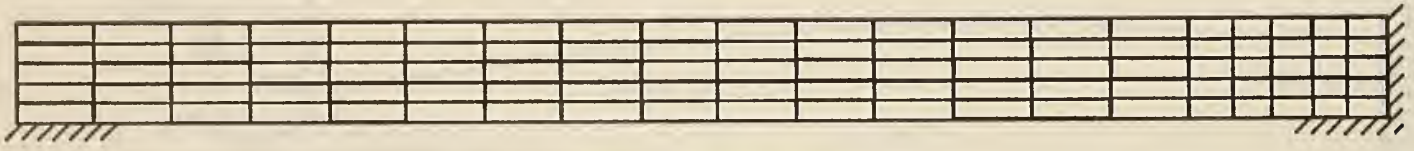


CASE 2 L/H = 6.0



CASE 3 L/H = 10.0

R = a/b



CASE 4 L/H = 14.0

CASE 5 L/H = 22.0

FIG. 33 RIGID WALL SYSTEM FOR STUDYING THE EFFECTS OF LATERAL EXTENT OF BACKFILLS

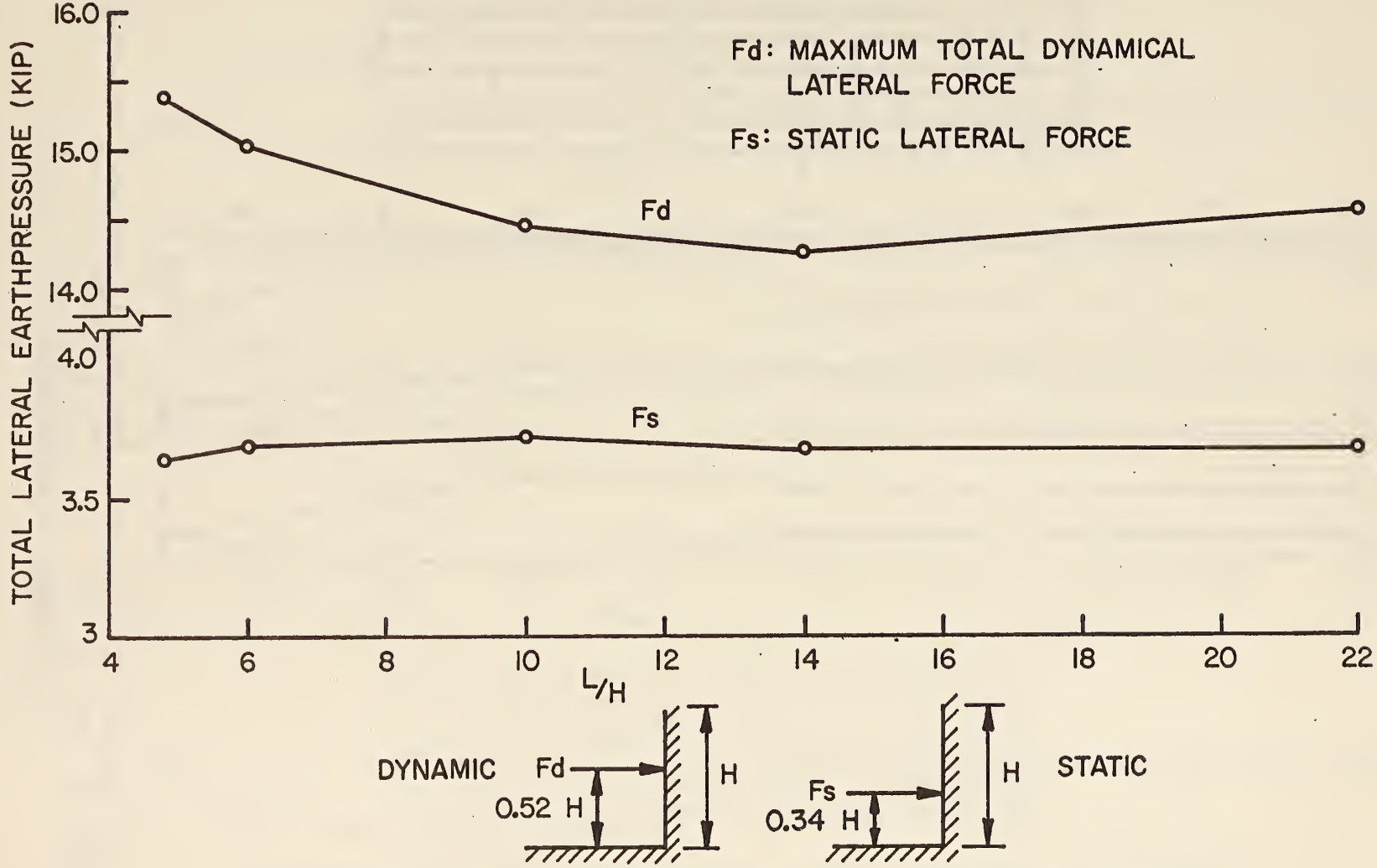


FIG. 34 STATIC AND MAXIMUM DYNAMICAL TOTAL LATERAL EARTHPRESSURE FOR DIFFERENT LATERAL EXTENT L/H

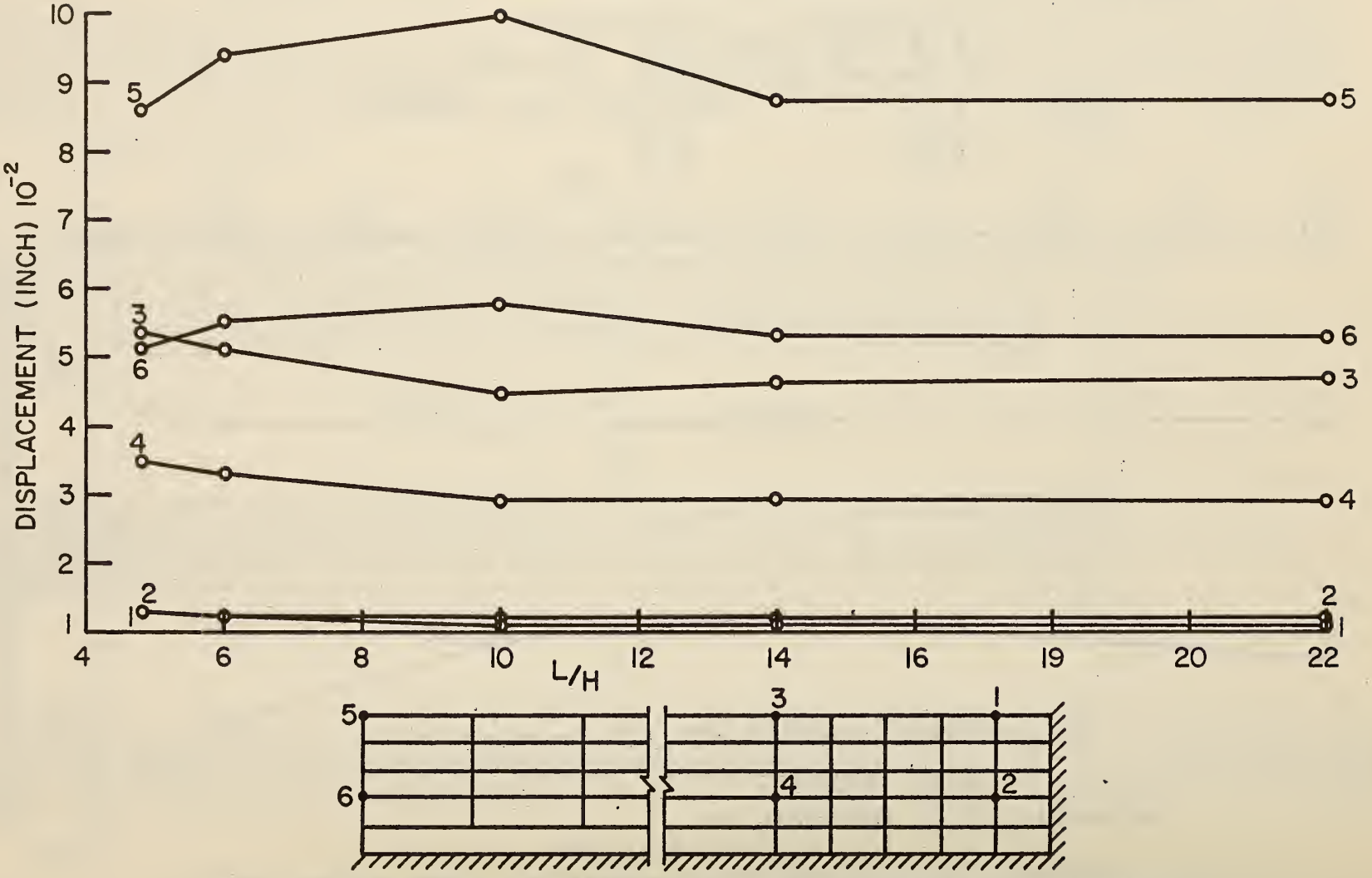


FIG. 35 MAXIMUM HORIZONTAL DISPLACEMENT AT POINTS 1 TO 6 FOR DIFFERENT LATERAL EXTENT L/H

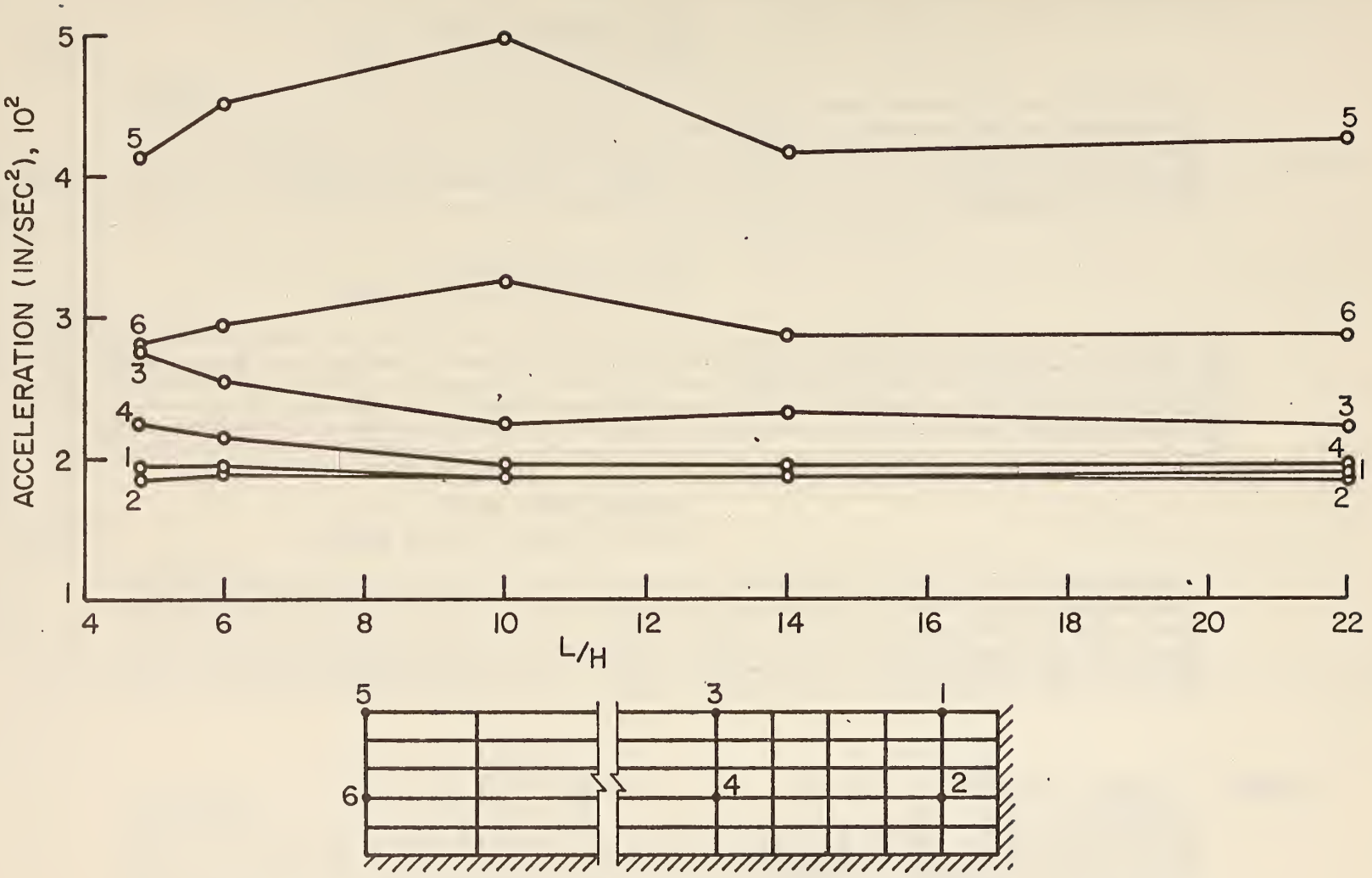
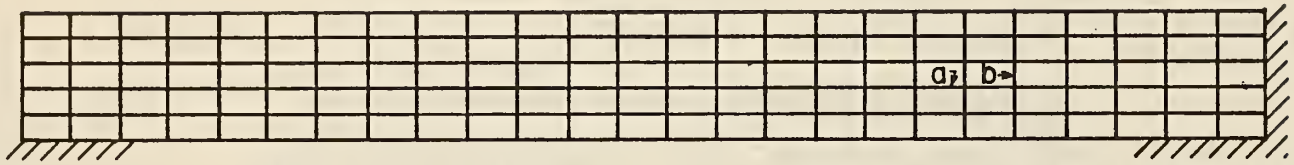
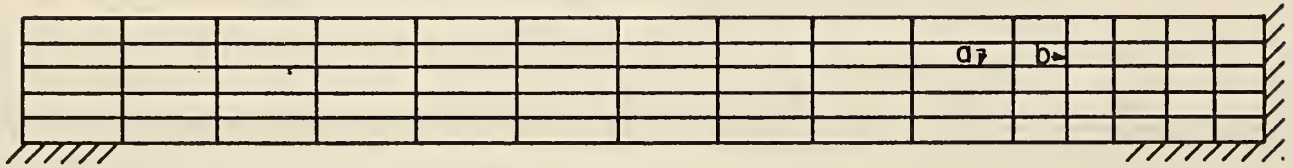


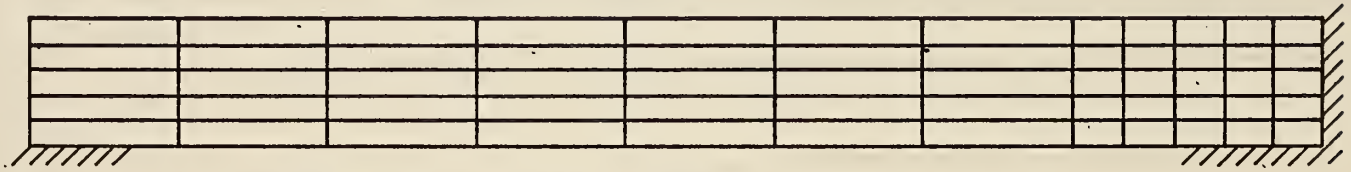
FIG. 36 MAXIMUM HORIZONTAL ACCELERATIONS AT POINTS 1 TO 6 FOR DIFFERENT LATERAL EXTENT L/H



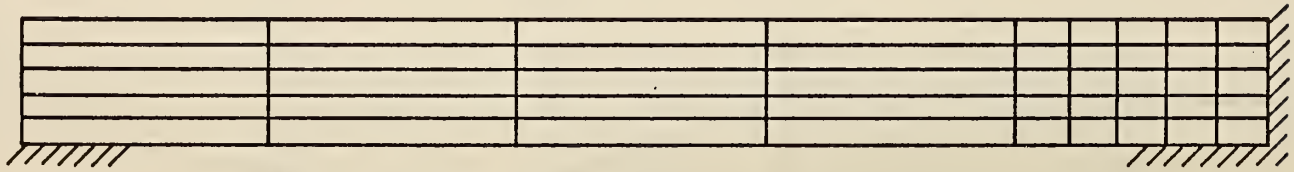
CASE 1, R = 2 UNIFORMLY R = a/b L/H = 10.0 FOR ALL CASES



CASE 2, R = 2 FOR X < 2H
R = 4 FOR X > 2H



CASE 3, R = 2 FOR X < 2H
R = 6 FOR X > 2H



CASE 4, R = 2 FOR X < 2H
R = 10 FOR X > 2H

FIG. 37 FINITE ELEMENT MODEL FOR STUDYING THE LENGTH TO HEIGHT RATIO R

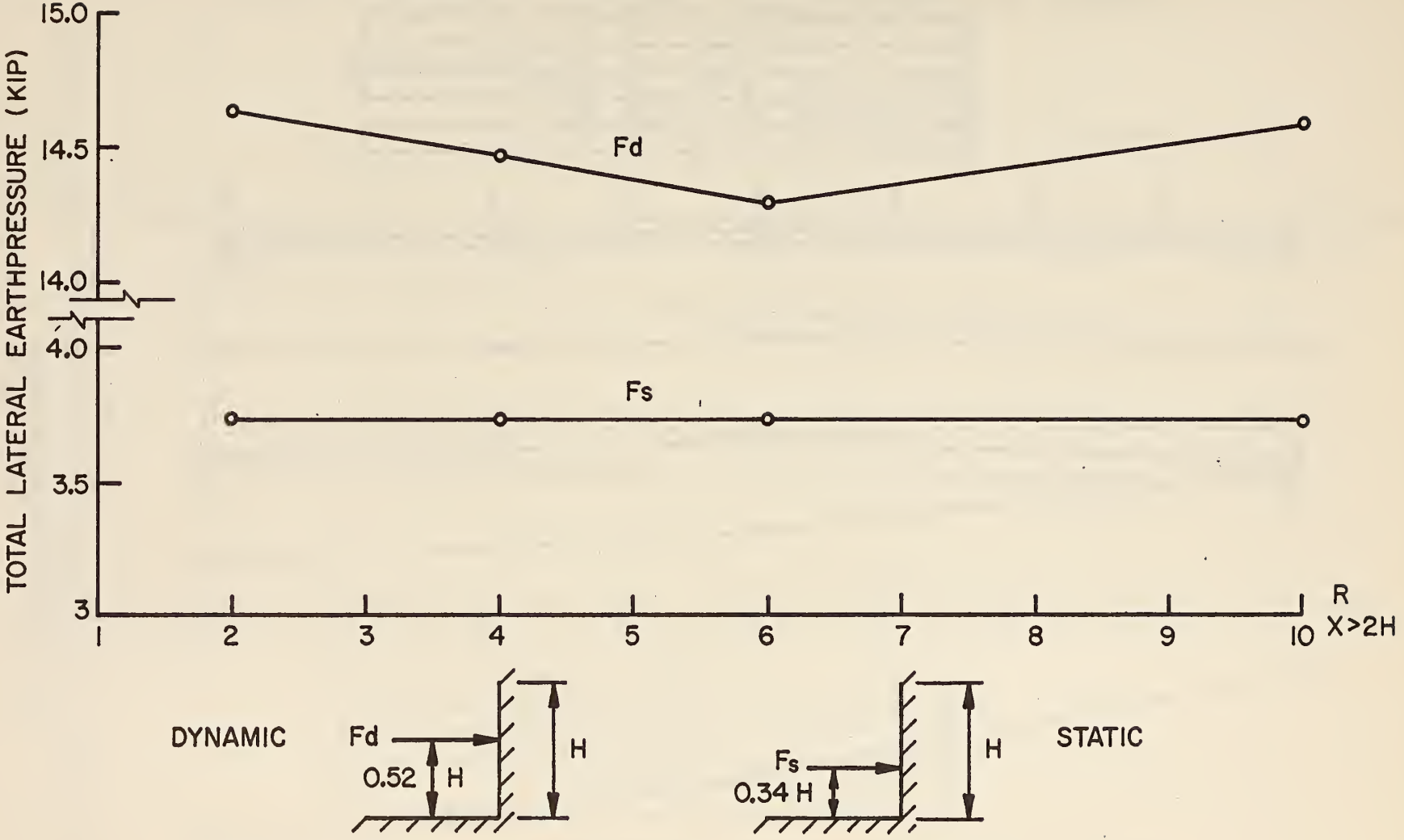


FIG. 38 STATIC AND MAXIMUM DYNAMICAL TOTAL LATERAL PRESSURE FOR DIFFERENT ELEMENT SIZE R= a/b

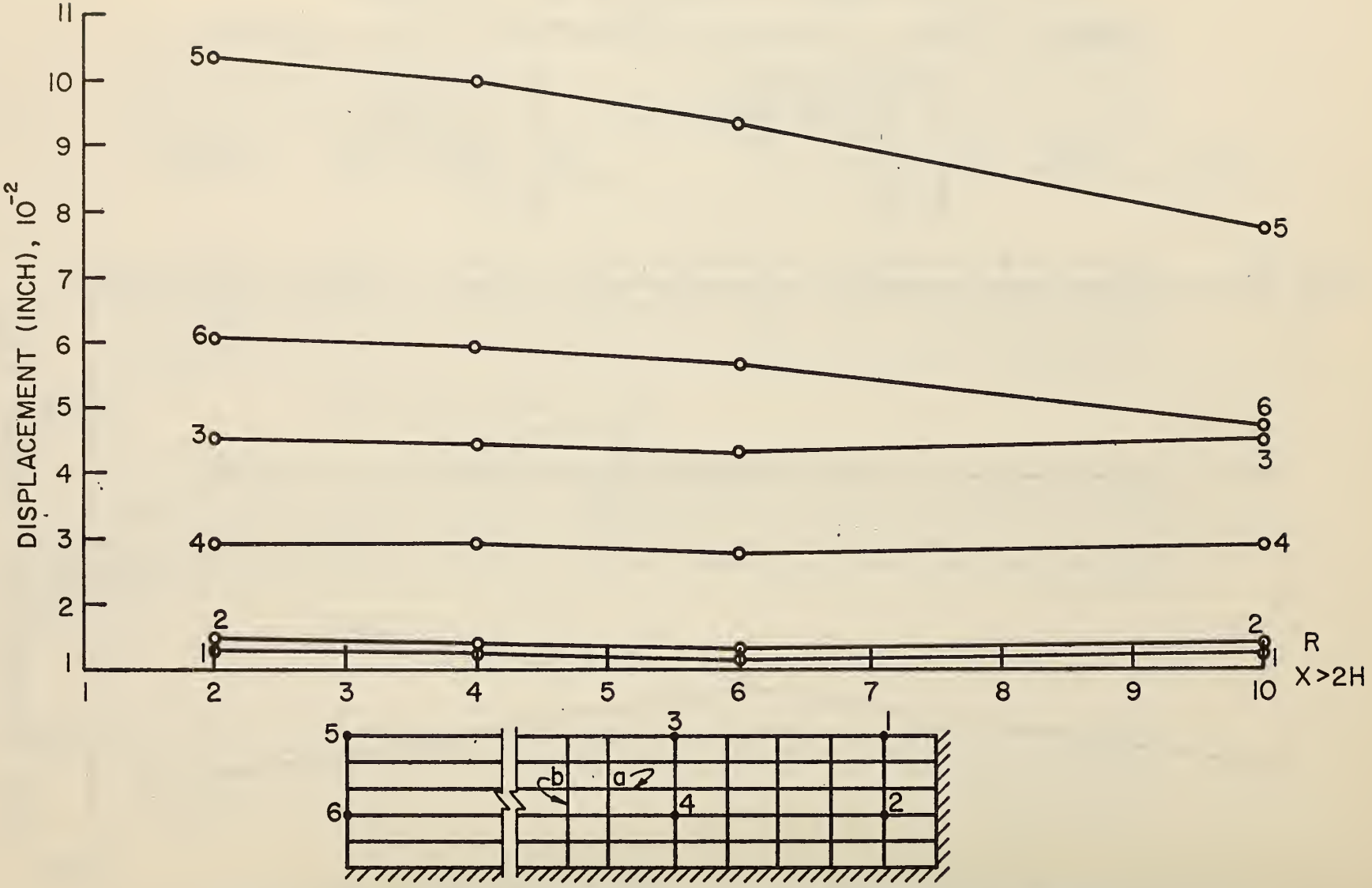


FIG.39 MAXIMUM HORIZONTAL DISPLACEMENT AT POINTS 1 TO 6 FOR DIFFERENT ELEMENT SIZE R= a/b

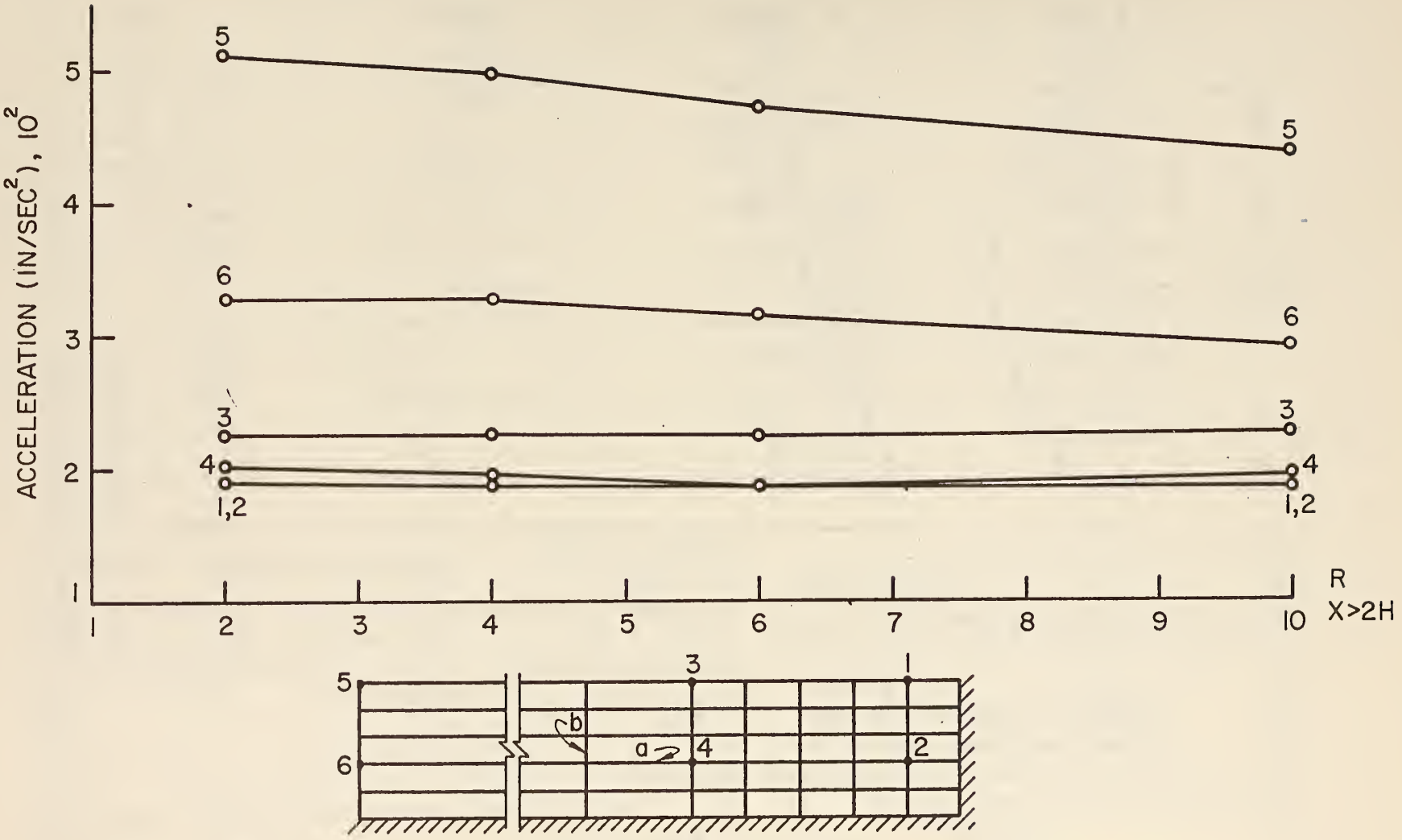


FIG. 40 MAXIMUM HORIZONTAL ACCELERATION AT POINTS 1 TO 6 FOR DIFFERENT ELEMENT SIZE R = a/b

CASE	TOTAL LAYERS	SUBDIVISION	Fs	Fd	REMARKS
			%		
1	5	R = 2 FOR X < 2H R = 10 FOR X > 2H	95.2	94.2	1. Fs, Fd ARE THE STATIC AND MAXIMUM DYNAMIC LATERAL FORCES 2. CASE 2 AS BASIS FOR CALCULATING PERCENTAGES
2	10	L/H = 10	100	100	
CASE 2, ABSOLUTE VALUES			KIPS		
			3.91	15.32	

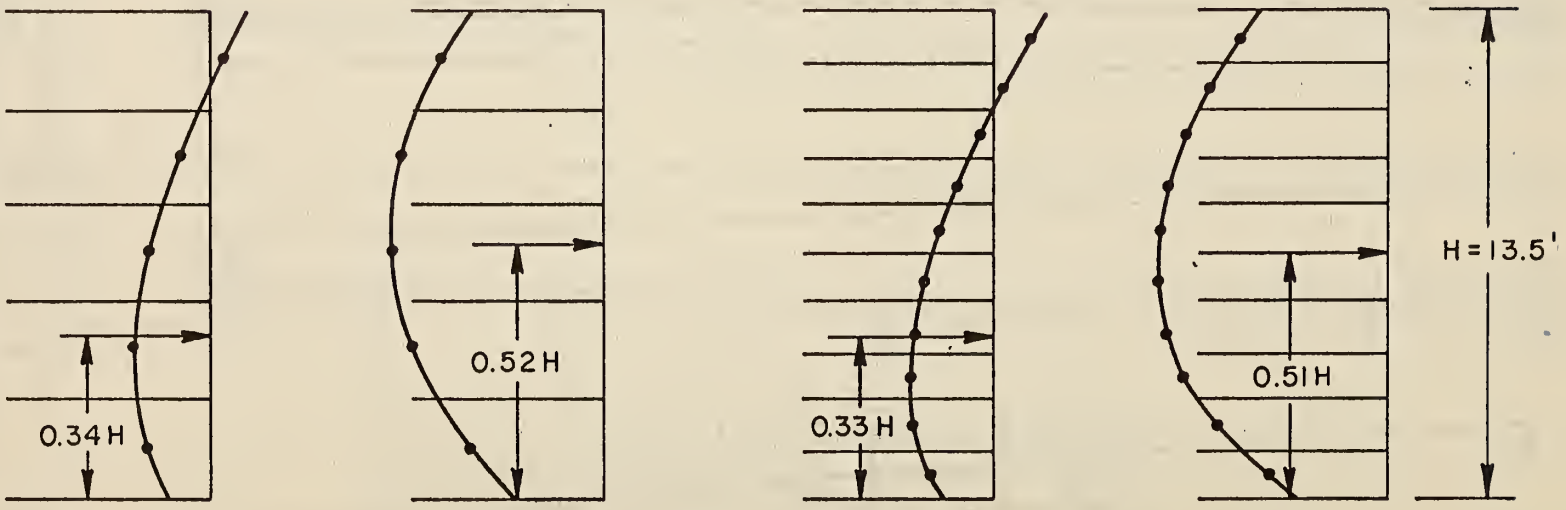
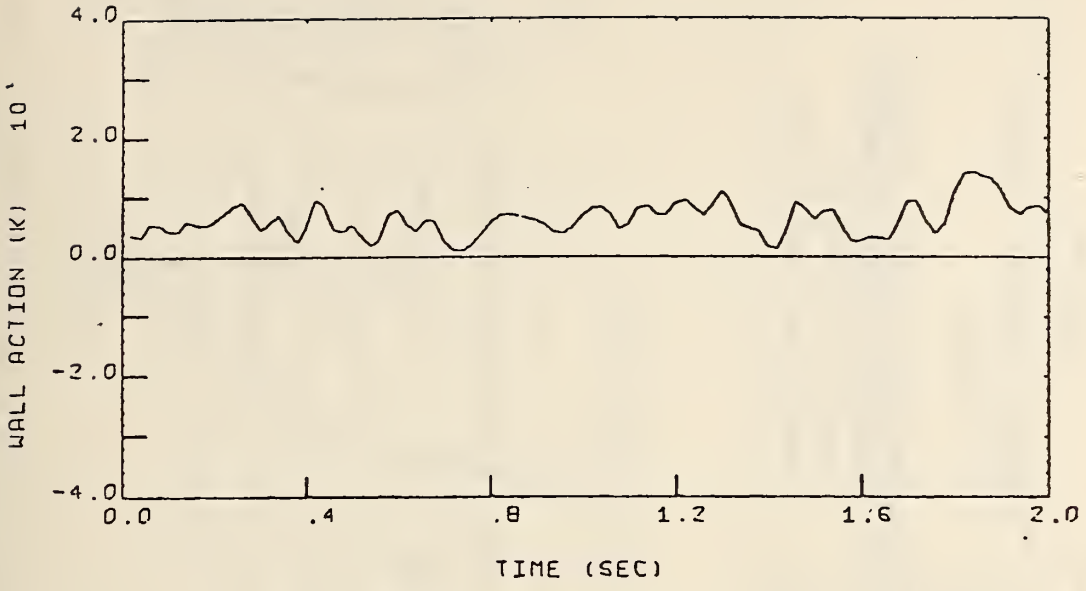
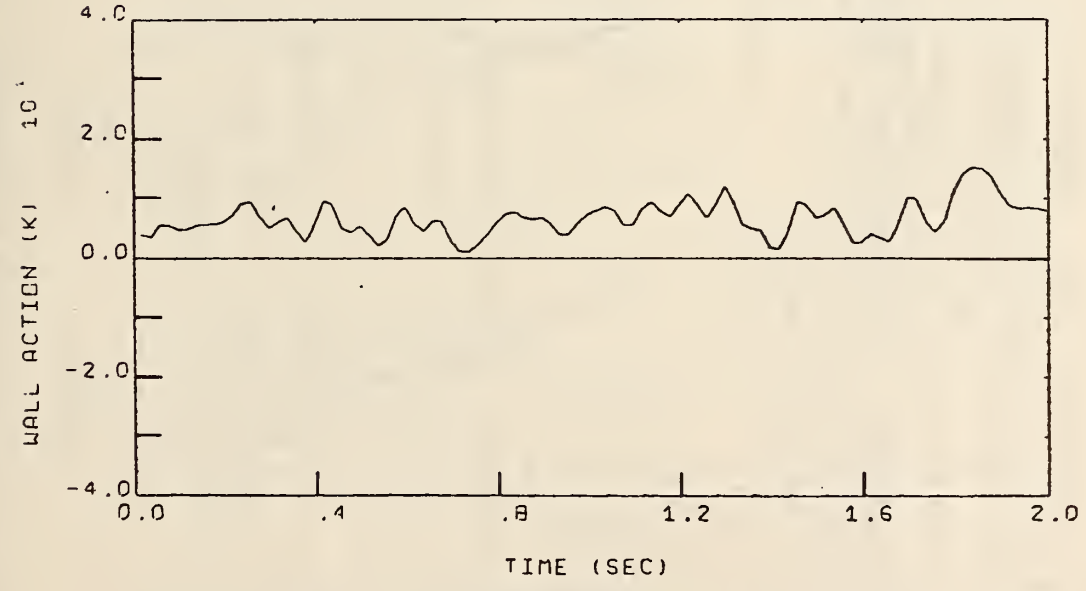


FIG. 41 STATIC AND MAXIMUM DYNAMICAL PRESSURE DISTRIBUTION WITH DIFFERENT NUMBER OF LAYERS - RIGID WALL SYSTEM



(a) 5 LAYERS



(b) 10 LAYERS

FIG. 42 TOTAL LATERAL EARTHPRESSURE – RIGID WALL SYSTEM

CASE	SUBDIVISION	SOIL PROPERTY	Fs	Fd	REMARKS
			%		
1	R=2 FOR X<2H	G=10.0 UNIFORM	101.3	110.5	1. REFER TO FIG. 37 , CASE 4 FOR MODEL 2. CASE 3, THE NON-UNIFORM MODULUS CASE AS BASES FOR CALCULATING THE PERCENTAGE FOR $K_2 = 50$
2	R=10 FOR X>2H	G= 2.5 UNIFORM	101.3	154.0	
3	L/H = 10.0	$G=1000.K_2(\sigma m)^{1/2}$	100	100	
CASE 3, ABSOLUTE VALUE			KIPS		
			3.67	13.06	

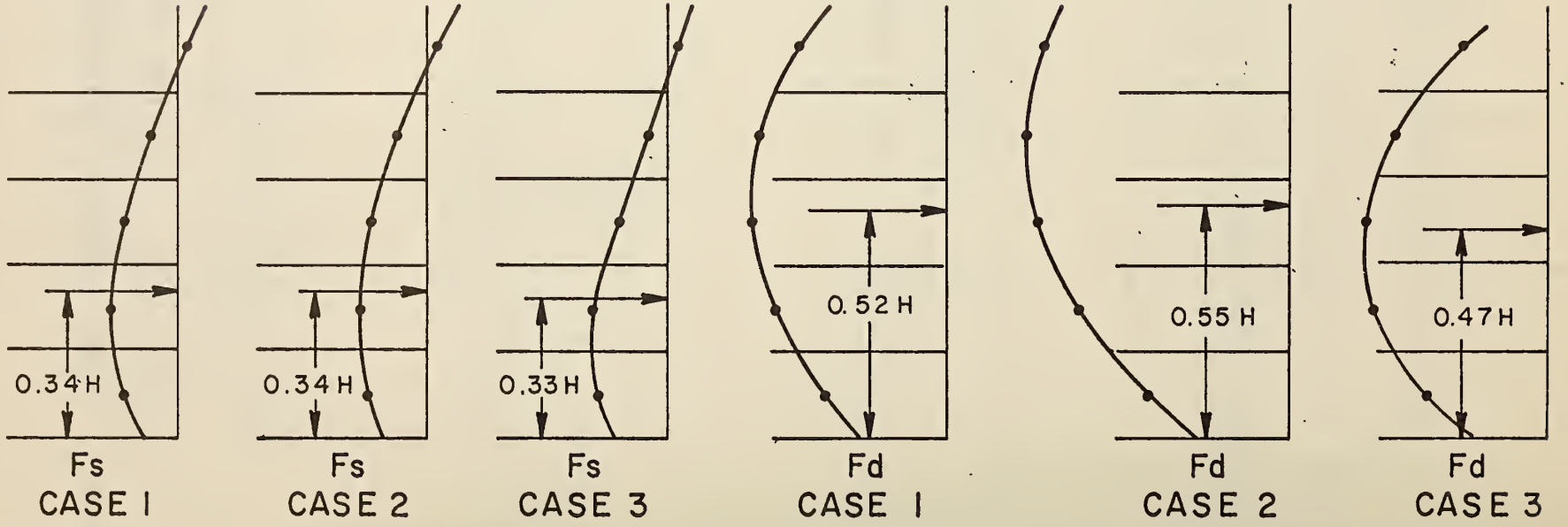
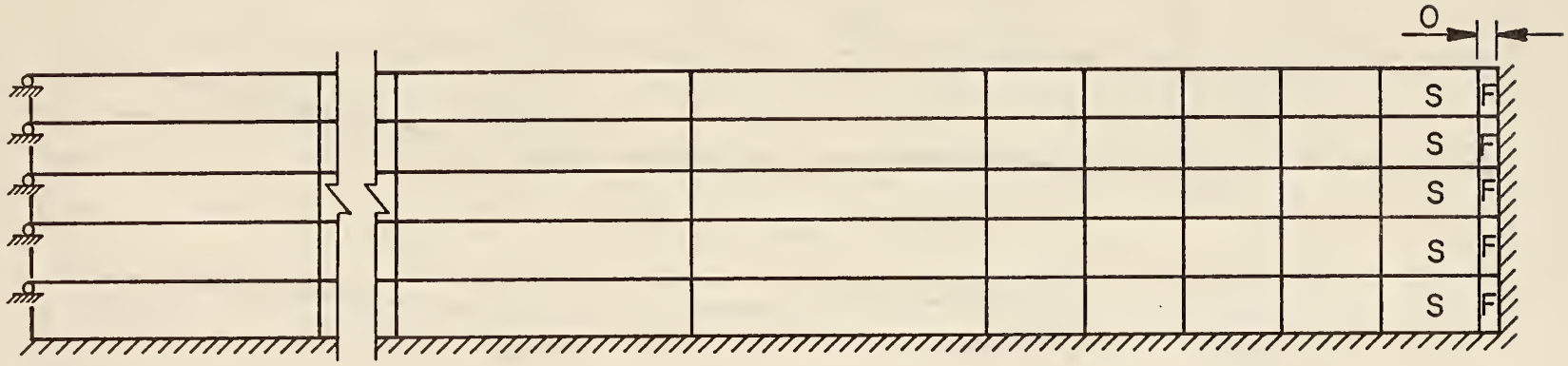


FIG. 43 STATIC AND MAXIMUM DYNAMICAL PRESSURE DISTRIBUTION WITH DIFFERENT SOIL PROPERTIES - RIGID WALL SYSTEM



$R \approx 2$ FOR $X < 2H$
$R \approx 6$ FOR $X > 2H$
$L/H = 115/13.5 = 8.5$
$G = 10.0$ KSI

$K_S = K_N$ RANGING $1, 10^3, 10^6, 10^9$ KSI
F: THE FRICTIONAL ELEMENTS NEAR WALL
S: SOIL ELEMENT

FIG. 44 MODEL FOR STUDYING FRICTIONAL ELEMENT, RIGID WALL SYSTEM

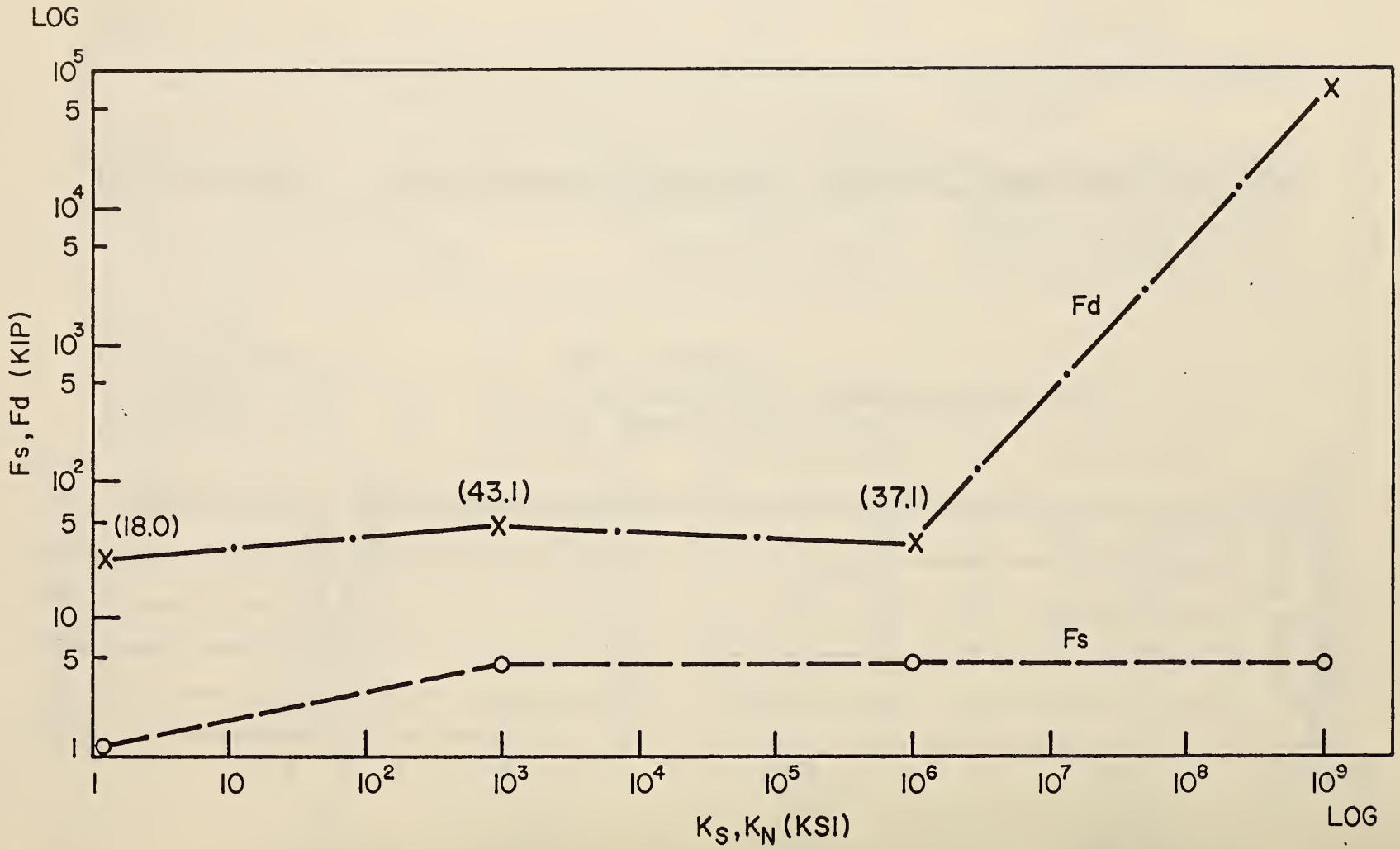
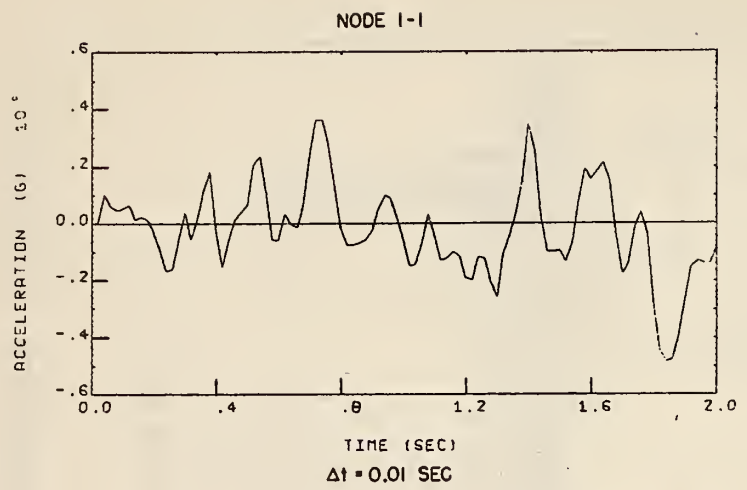
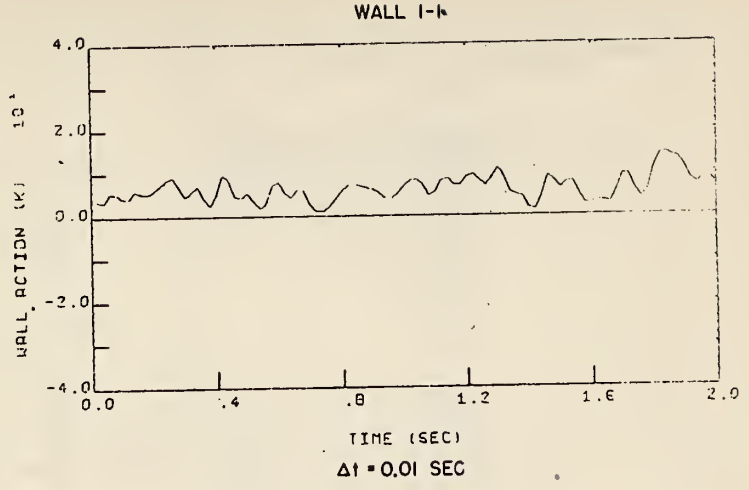
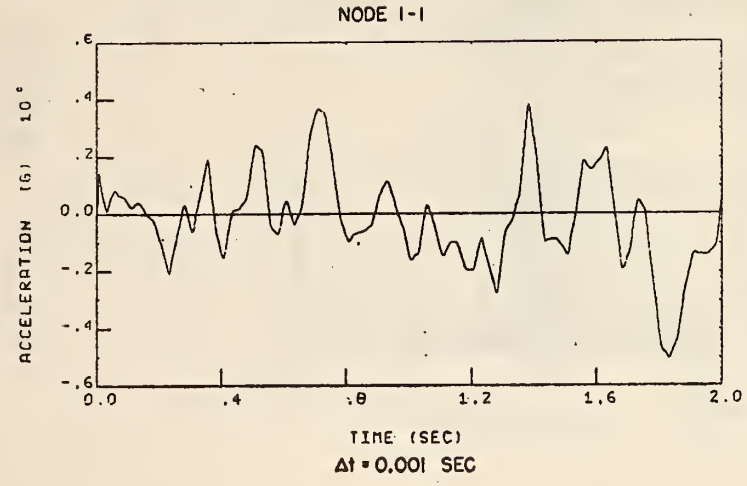


FIG. 45 EFFECT OF STIFFNESS OF FRICTIONAL ELEMENT ON TOTAL LATERAL FORCE - RIGID WALL SYSTEM







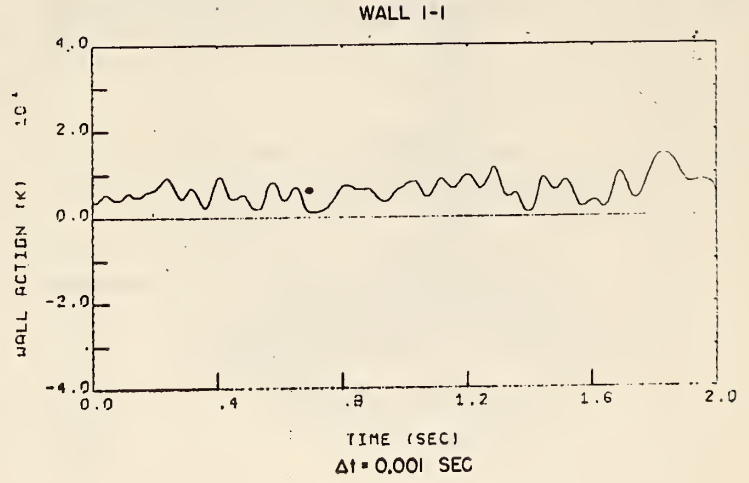
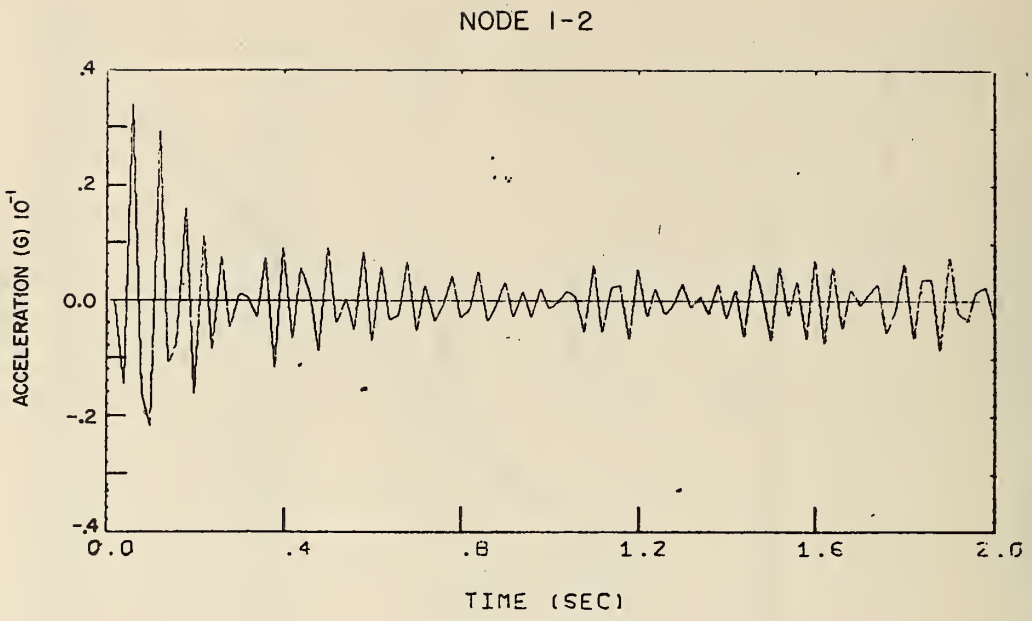
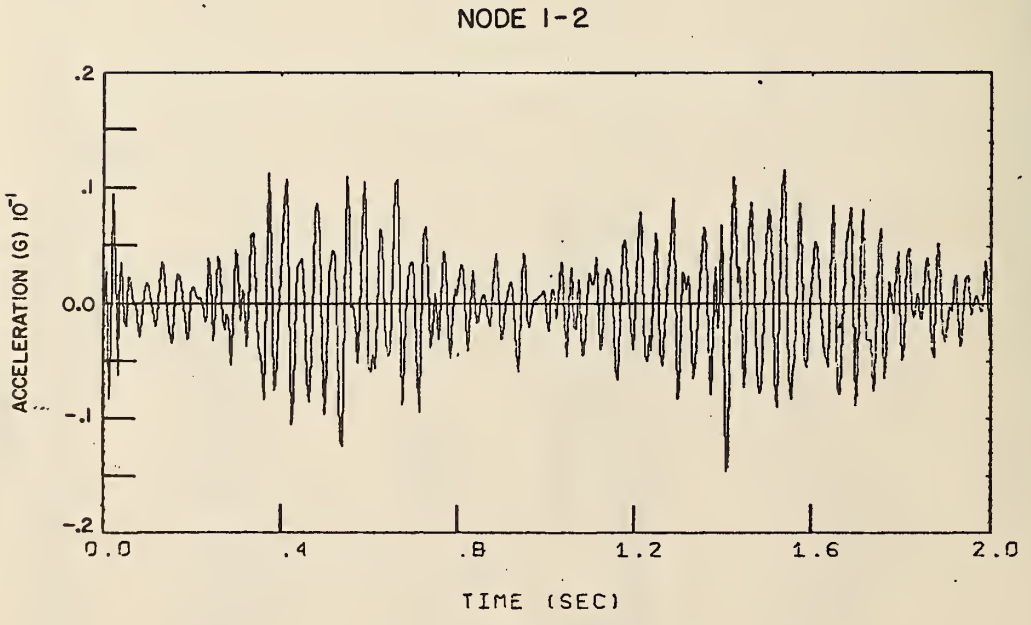


FIG. 46 LATERAL FORCE AND HORIZONTAL ACCELERATION AT POINT NO. 1 - RIGID WALL SYSTEM

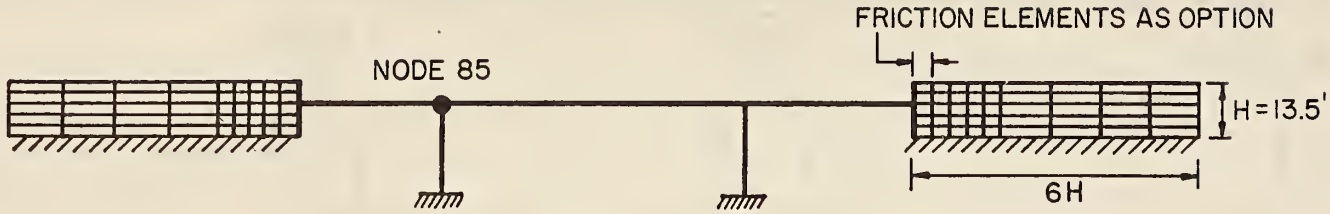


(a) $\Delta t = 0.01$ SEC

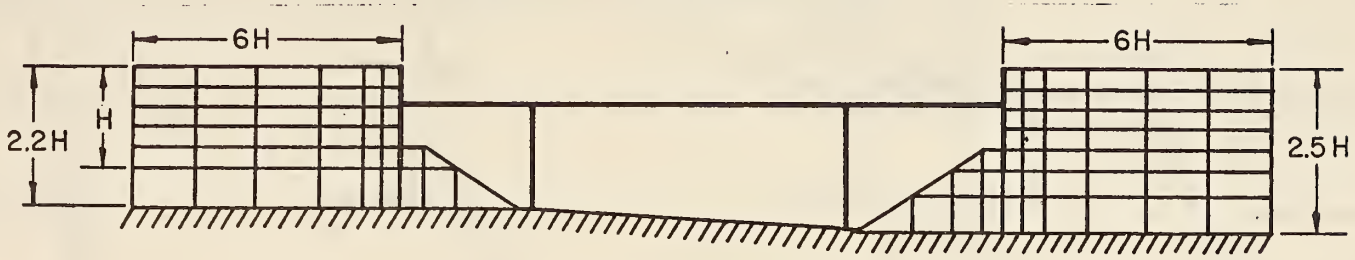


(b) $\Delta t = 0.001$ SEC

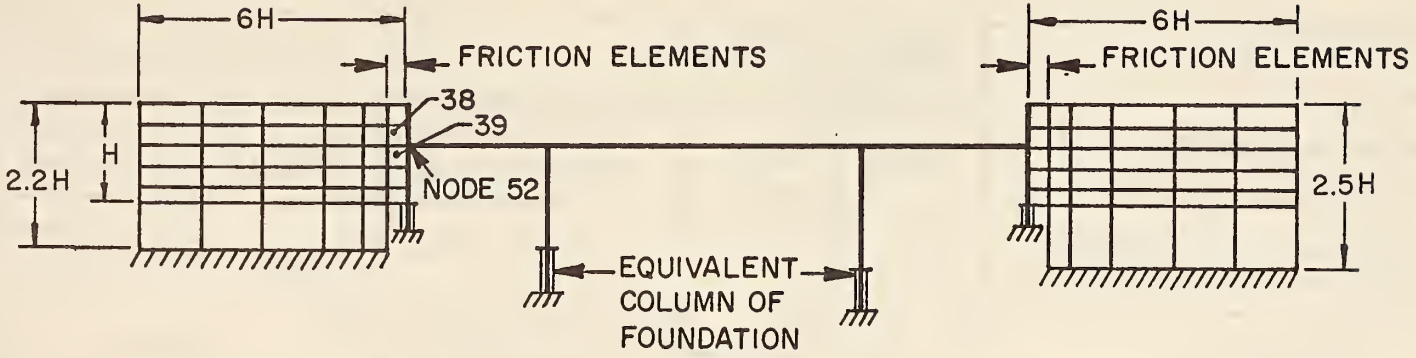
FIG. 47 VERTICAL ACCELERATION AT POINT NO. 1



A. ABUTMENT BASE FIXED



B. ABUTMENT ON SOIL



C. SUBSTRUCTURES ON EQUIVALENT COLUMNS

FIG. 48 NORTH CONNECTOR UNDERCROSSING, BRIDGE-SOIL SYSTEMS

CASE	SYSTEM	MOVEMENT AT ABUTMENT BASE	F_s	F_d	REMARKS
			%		
1	BRIDGE-SOIL SYSTEM FIXED BASE	NO MOVEMENT	100	100	1. ALL SOILS ARE ASSUMED UNIFORM, WITH G=10 KSI 2. CASE 1, REFER TO FIG. 48-A CASE 2, REFER TO FIG. 48-B
2	BRIDGE-SOIL SYSTEM COLUMN ON SOIL	ROTATION AND TRANSLATION	83.0	270.0	
CASE 1, ABSOLUTE VALUE			KIPS		
			3.42	6.32	

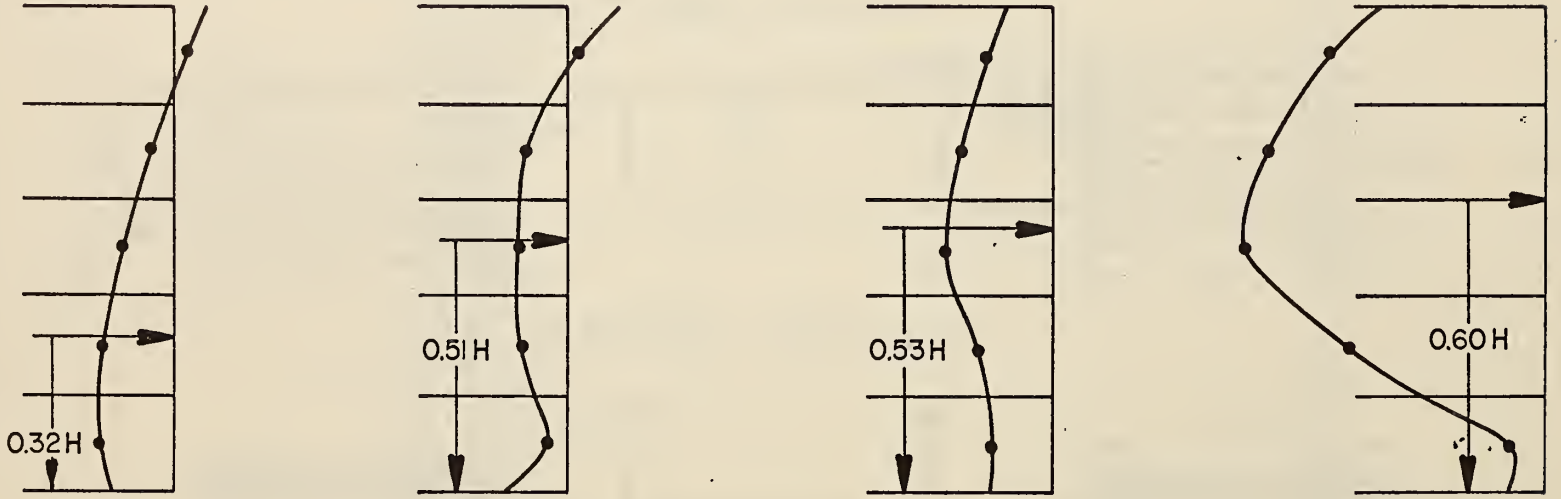


FIG. 49 STATIC AND MAXIMUM DYNAMICAL PRESSURE DISTRIBUTION WITH DIFFERENT BOUNDARY CONDITIONS AT THE BASE OF ABUTMENT

CASE	SYSTEM	PERIOD, SEC.		Fs	Fd	REMARKS
		1 st.	10 th.	%		
1	BRIDGE-SOIL SYSTEM FIXED BASE	0.195	0.063	100	100	1. ALL SOILS ARE ASSUMED UNIFORM, WITH G = 10 KSI
2	SAME AS 1, EXCEPT WITH SOFTER SUB-STRUCTURE	0.232	0.076	120.0	175.0	2. REFER TO FIG. 48-A FOR THE MODEL
CASE 1, ABSOLUTE VALUE				KIPS		
				3.42	6.32	

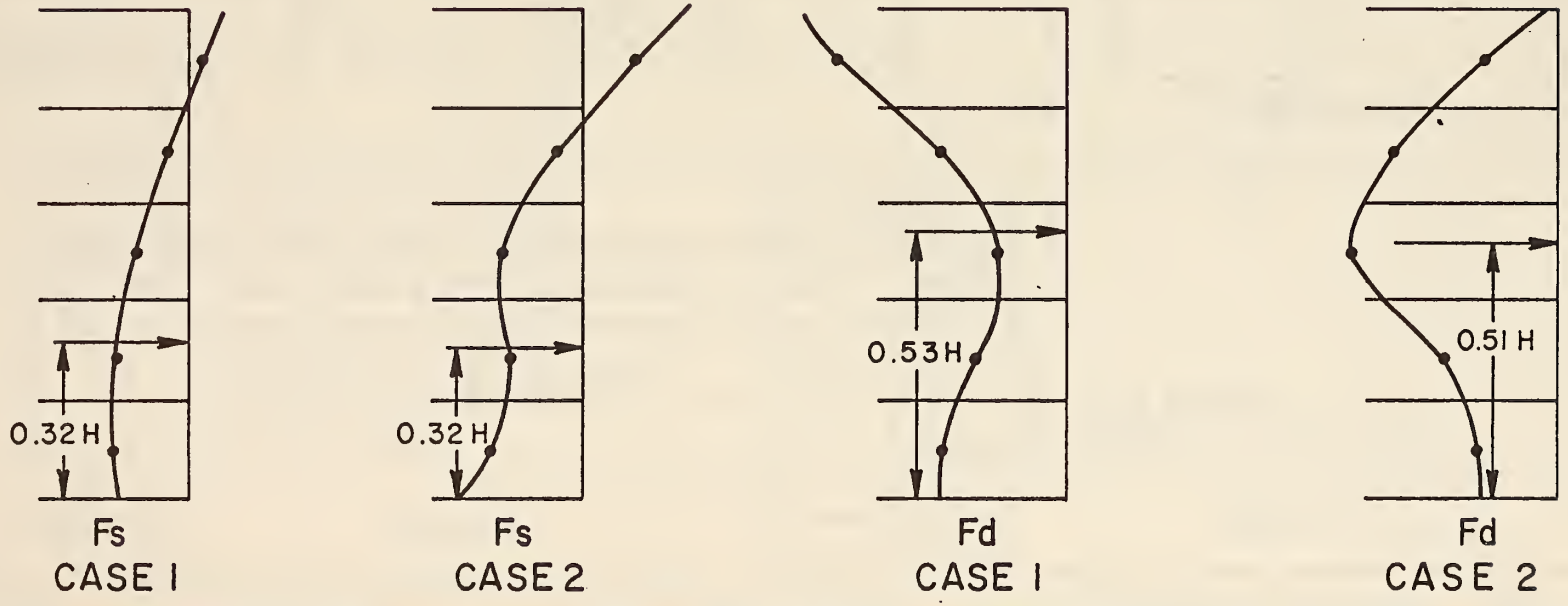


FIG. 50 STATIC AND MAXIMUM DYNAMICAL PRESSURE DISTRIBUTION OF BRIDGE-SOIL SYSTEM WITH DIFFERENT SUBSTRUCTURES

CASE	SYSTEM	Fs	Fd	REMARKS
		%		
1	LINEAR MODEL	100	100	1. REFER TO FIG. 48-A FOR MODEL
2	LINEAR SOIL, NON-LINEAR FRICTION	88.0	612.0	
3	NON-LINEAR SOIL, FRICTION	80.5	520.0	
CASE 1, ABSOLUTE VALUES		KIPS		
		3.42	6.75	

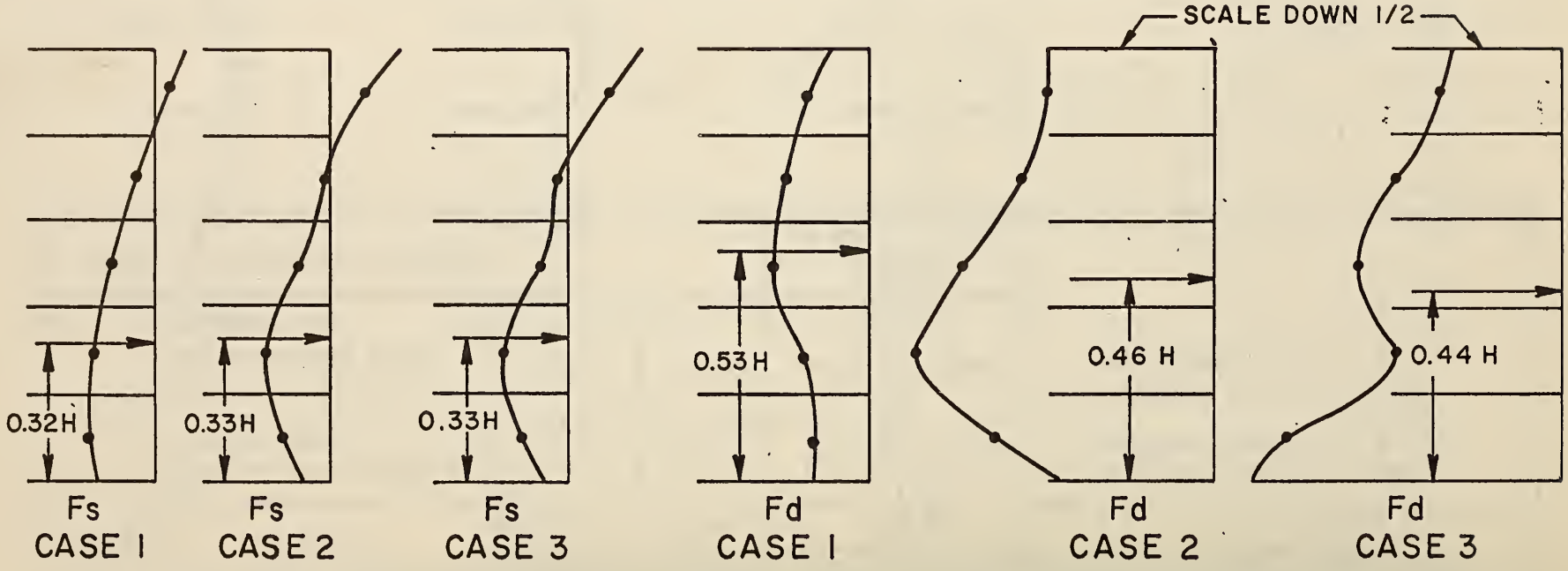


FIG. 51 STATIC AND DYNAMIC PRESSURE DISTRIBUTION OF BRIDGE-SOIL SYSTEM WITH DIFFERENT DEGREES OF NON-LINEARITY

CASE	SYSTEM	FOUNDATION	Fs	Fd	REMARKS
			%		
1	BRIDGE-SOIL SYSTEM WITH NON-LINEAR FRICTION ELEMENT, THE REST IS LINEAR	FIXED AT TOP OF EQ.COL.	100	100	1. REFER TO FIG. 48-C FOR MODEL
2		WITH EQUIVALENT COLUMN	129.0	225.0	
CASE 1, ABSOLUTE VALUES			KIPS		
			3.30	15.3	

SCALE DOWN 1/2 FOR Fd

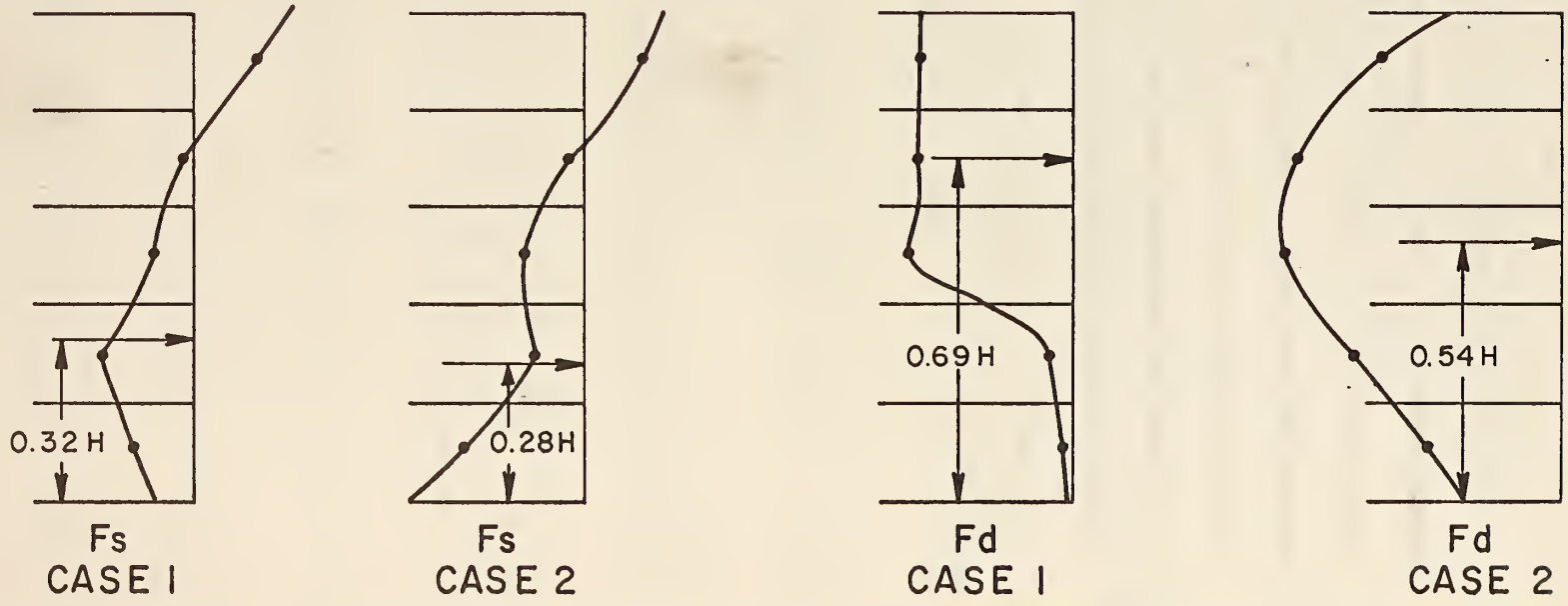


FIG. 52 STATIC AND MAXIMUM DYNAMICAL PRESSURE DISTRIBUTION OF BRIDGE-SOIL SYSTEM WITH DIFFERENT FOUNDATION

VII GENERAL CONCLUSION

Based on the results of this investigation, it is concluded that soil-structure interaction effects must be considered when analyzing the dynamic response of short, stiff, single or multiple span bridges. The mathematical modelling and computer programs presented herein provide an effective means of conducting such analyses.

Since the numerical results obtained in this investigation are very limited, caution should be exercised when interpreting them in a quantitative sense. Further analyses are recommended to complete the parameter studies.

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APPENDIX

Computer Program Listings

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      PROGRAM BRISOT(INPUT,OUTPUT,TAPE6=OUTPUT,TAPE1,TAPE3,TAPE4,TAPE10,BRISOT.1
     1               TAPE11,TAPE12,TAPE13,TAPE14,TAPE21,TAPE22,TAPE23,  BRISOT.2
     2              TAPE7,TAPE30,TAPE20,TAPE40,TAPE41)                  BRISOT.3
C                                                                       BRISOT.4
C     ******************************************************************BRISOT.5
C     TWO DIMENSIONAL NONLINEAR DYNAMIC ANALYSIS OF SOIL-BRIDGE INTERACTBRISOT.6
C     JULY,1973-NA-CHI CHEN                                             BRISOT.7
C     ******************************************************************BRISOT.8
      COMMON/TITLE/HEAD(12),EQNAME(12)                                  BRISOT.9
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NINTCV,THICKBRISOT.10
     ),NPLAN                                                            BRISOT.11
      COMMON/ELPAR/NUMNP,NUMEL,NEQ,NBAND,KLIN                           BRISOT.12
      COMMON/TIME/JUMP,T,DT,NPRTN,NTAPE,KPRINT                          BRISOT.13
      COMMON/ABS/UGXT,UGYT,VGXT,VGYT,OACCX,OACCY                        BRISOT.14
      COMMON/SPECIL/ISTOP                                               BRISOT.15
      COMMON/OMEGA/OMEGA1,OMEGA2,NF1,NF2                                BRISOT.16
      COMMON/TAPES/NSTIF,NMASS                                          BRISOT.17
      DIMENSION S(3),NELW(10)                                           BRISOT.18
      COMMON A(35500)                                                   BRISOT.19
C                                                                       BRISOT.20
C     PROGRAM CONTROL DATA                                              BRISOT.21
C                                                                       BRISOT.22
 1000 CALL SECOND(S(1))                                                 BRISOT.23
      ISTOP=0                                                           BRISOT.24
      JUMP=0                                                            BRISOT.25
      READ 1,HEAD,NUMNP,NUMEL,NETYPE,KLIN,NUMATS,NUMATC,NUMATF,NUMATE,  BRISOT.26
     1       NUMATB,NUMGE,NINTCV,NPLAN,THICK                            BRISOT.27
      IF(NUMNP .EQ. 0) STOP                                             BRISOT.28
      WRITE(6,101)  HEAD,NUMNP,NUMEL,NETYPE,KLIN,NUMATS,NUMATC,NUMATF,  BRISOT.29
     1              NUMATE,NUMATB,NUMGE,NINTCV,NPLAN,THICK              BRISOT.30
      READ 6,NF,NF1,NF2                                                 BRISOT.31
      WRITE(6,106) NF,NF1,NF2                                           BRISOT.32
C                                                                       BRISOT.33
C     INPUT JOINT DATA--IO(3,NUMNP)                                     BRISOT.34
C                                                                       BRISOT.35
      N1=1                                                              BRISOT.36
      N2=N1+3*NUMNP                                                     BRISOT.37
      N3=N2+NUMNP                                                       BRISOT.38
      N4=N3+NUMNP                                                       BRISOT.39
      CALL INPUTJ(A(N1),A(N2),A(N3),NUMNP,NEQ)                          BRISOT.40
      CALL SECOND(S(2))                                                 BRISOT.41
C                                                                       BRISOT.42
C     READ IN MATERIAL PROPERTIES DATA,AND BEAM,COLUMN GEOMETRIC DATA   BRISOT.43
C                                                                       BRISOT.44
      N5=N4+8*NUMATS                                                    BRISOT.45
      N6=N5+5*NUMATC                                                    BRISOT.46
      N7=N6+4*NUMATF                                                    BRISOT.47
      N8=N7+4*NUMATE                                                    BRISOT.48
      N9=N8+2*NUMATB                                                    BRISOT.49
      N10=N9+3*NUMGE                                                    BRISOT.50
      N11=N10+20*NUMATS                                                 BRISOT.51
      N12=N11+9*NINTCV                                                  BRISOT.52
      DO 301 I=1,NETYPE                                                 BRISOT.53
      READ 2,NTYPE                                                      BRISOT.54
      WRITE(6,102) NTYPE                                                BRISOT.55
      CALL MATPRO(NTYPE,A(N4),A(N5),A(N6),A(N7),A(N8),A(N9),A(N10),     BRISOT.56
     1A(N11))                                                           BRISOT.57
  301 CONTINUE                                                          BRISOT.58
      CALL SECOND(S(3))                                                 BRISOT.59
C                                                                       BRISOT.60
C     READ IN ELEMENT DATA                                              BRISOT.61
C                                                                       BRISOT.62
      N13=N12+6*NUMEL                                                   BRISOT.63
      N14=N13+4*NUMEL                                                   BRISOT.64
      CALL ELDATA(A(N1),A(N12),A(N13),NBAND,NUMEL)                      BRISOT.65
      CALL SECOND(S(4))                                                 BRISOT.66
C                                                                       BRISOT.67
C     INPUT AND CALCULATE NODAL MASS,LOAD,AND FIXED END MOMENT OF BEAM  BRISOT.68
C                                                                       BRISOT.69
      N15=N14+NEQ                                                       BRISOT.70
      N16=N15+NEQ                                                       BRISOT.71
      N17=N16+NEQ                                                       BRISOT.72
      NT18=N17+NEQ                                                      BRISOT.73
      NT19=NT18+NEQ                                                     BRISOT.74
      CALL LOAD(A(N1),A(N2),A(N3),A(N4),A(N5),A(N9),A(N12),A(N13),      BRISOT.75
     1A(N14),A(N15),A(N16),A(N17),A(NT18),NUMEL,NEQ)                    BRISOT.76
      CALL SECOND(S(5))                                                 BRISOT.77
C                                                                       BRISOT.78
C                                                                       BRISOT.79
C     FORM ELASTIC STRESS-STRAIN RELATIONSHIP                           BRISOT.80
      NT18=N17+5*NUMEL                                                  BRISOT.81
      NT19=NT18+NUNGE                                                   BRISOT.82
      NT20=NT19+5*NUMATS                                                BRISOT.83
      NT21=NT20+5*NUMATC*NUMGE                                          BRISOT.84
      NT22=NT21+9*NUMATF                                                BRISOT.85
      NT23=NT22+5*NUMATE                                                BRISOT.86
      NT24=NT23+5*NUMATB                                                BRISOT.87
      CALL ESGEPS(A(N2),A(N3),A(N4),A(N5),A(N6),A(NT),A(N8),A(N9),      BRISOT.88
     1A(N12),A(N13),A(N17),A(NT18),A(NT19),A(NT20),A(NT21),A(NT22),     BRISOT.89
     2A(NT23),NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NPLAN)           BRISOT.90
      CALL SECOND(S(6))                                                 BRISOT.91
C                                                                       BRISOT.92
C                                                                       BRISOT.93
C     FORM TOTAL ELASTIC STIFFNESS FOR STATIC ANALYSIS                  BRISOT.94
C                                                                       BRISOT.95
      N18=N17+5*NUMEL                                                   BRISOT.96
      N19=N18+NEQ*NBAND                                                 BRISOT.97
      NT20=N19+NUMEL                                                    BRISOT.98
      CALL ETSTIF(A(N1),A(N2),A(N3),A(N5),A(N9),A(N12),A(N13),A(N14),   BRISOT.99
     1            A(N17),A(N18),A(N19),NUMEL,NEQ,NBAND)                 BRISOT.100
      CALL SECOND(S(7))                                                 BRISOT.101
C                                                                       BRISOT.102
C     CALCULATE LOWEST ?NF? FREQUENCIES                                 BRISOT.103
C                                                                       BRISOT.104
      CALL MODES(NEQ,NBAND,1,NF,NTOT,N18)                               BRISOT.105
C                                                                       BRISOT.106
C     SOLVE FOR DISPLACEMENT-STATIC CASE                                BRISOT.107
C                                                                       BRISOT.108
      JUMP=0                                                            BRISOT.109
      N20=N19+NEQ                                                       BRISOT.110
      N21=N20+NEQ                                                       BRISOT.111
      N22=N21+NEQ                                                       BRISOT.112
      N23=N22+NEQ                                                       BRISOT.113
      N24=N23+NEQ                                                       BRISOT.114
      N25=N24+NEQ                                                       BRISOT.115
      CALL STATIC(A(N14),A(N18),A(N19),A(N20),A(N21),A(N22),A(N23),     BRISOT.116
     1A(N24),NEQ,NBAND)                                                 BRISOT.117
      CALL SECOND(S(8))                                                 BRISOT.118
C                                                                       BRISOT.119
C     COMPUTE STRAIN                                                    BRISOT.120
C                                                                       BRISOT.121
      N26=N25+3*NUMEL                                                   BRISOT.122
      N27=N26+3*NUMEL                                                   BRISOT.123
      N28=N27+3*NUMEL                                                   BRISOT.124
      CALL STRAIN(A(N1),A(N2),A(N3),A(N12),A(N22),A(N25),A(N26),A(N27)) BRISOT.125
      CALL SECOND(S(9))                                                 BRISOT.126
C                                                                       BRISOT.127
C     COMPUTE STRESS                                                    BRISOT.128
C                                                                       BRISOT.129
      N29=N28+8*NUMEL                                                   BRISOT.130
      N30=N29+8*NUMEL                                                   BRISOT.131
      N31=N30+4*NUMEL                                                   BRISOT.132
      CALL STRESS(A(N12),A(N22),A(N26),A(N28),A(N29),A(N30))            BRISOT.133
      CALL SECOND(S(10))                                                BRISOT.134
C                                                                       BRISOT.135
C     INPUT ABUTMENT WALL INFORMATION,CALCULATE EARTHPRESS ON WALL      BRISOT.136
C                                                                       BRISOT.137
      READ 3,NTW                                                        BRISOT.138
      IF(NTW .EQ. 0) GO TO 402                                          BRISOT.139
      READ 4,(NELW(I),I=1,NTW)                                          BRISOT.140
      WRITE(6,103) NTW,(NELW(I),I=1,NTW)                                BRISOT.141
      NL=0                                                              BRISOT.142
      DO 302 I=1,NTW                                                    BRISOT.143
      LENGTH=3*NELW(I)                                                  BRISOT.144
      IF(LENGTH .GT. NL) NL=LENGTH                                      BRISOT.145
  302 CONTINUE                                                          BRISOT.146
      GO TO 403                                                         BRISOT.147
  402 CONTINUE                                                          BRISOT.148
      N32=N31                                                           BRISOT.149
      N33=N32                                                           BRISOT.150
      N34=N33                                                           BRISOT.151
      N35=N34                                                           BRISOT.152
      IF(NTW .EQ. 0) GO TO 401                                          BRISOT.153
  403 CONTINUE                                                          BRISOT.154
      LENGTH=NTW*NL                                                     BRISOT.155
      N32=N31+LENGTH                                                    BRISOT.156
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      CALL WAOATA(NELW,A(N3I),NTW)                                      BRISOT.157
      N33=N32+NTW                                                       BRISOT.158
      N34=N33+NTW                                                       BRISOT.159
      N35=N34+NTW                                                       BRISOT.160
      CALL WFORCE(A(N3),A(N12),A(N29),NELW,AIN31),AIN32),AIN33),A(N34), BRISOT.161
     1            NTW)                                                 BRISOT.162
  401 CONTINUE                                                          BRISOT.163
      CALL SECOND(S(11))                                                BRISOT.164
C                                                                       BRISOT.165
C     PRINT RESULTS,AND STORE ON TAPE2 FOR PLOTTING                     BRISOT.166
C                                                                       BRISOT.167
      NUMELE=NUMEL                                                      BRISOT.168
      N36=N35+NUMEL                                                     BRISOT.169
      N3T=N36+NUMEL                                                     BRISOT.1T0
      NT3B=N3T+9*NUMEL                                                  BRISOT.171
      CALL PRINTRIA(N1),A(N12),A(N19),AIN20),AIN21),A(N25),A(N2T),A(N29)BRISOT.1T2
     1,AIN30),AIN32),AIN33),A(N34),AIN35),AIN36),A(N37),NTW,NUMELE)     BRISOT.173
      CALL SECONDIS(I2))                                                BRISOT.1T4
C                                                                       BRISOT.175
C     START DYNAMIC ANALYSIS-STEP-BY-STEP                               BRISOT.176
C     FORM NONLINEAR TOTAL STIFFNESS                                    BRISOT.1T7
C                                                                       BRISOT.178
      N38=NT3B+36                                                       BRISOT.179
      CALL NTSTIF(A(N2),AIN3),A(N4),A(N5),A(N6),AIN7),A(N8),A(N9),      BRISOT.180
     1A(N10),A(N11),A(N12),A(N13),A(N14),AIN17),A(N18),A(N19),A(N20I,   BRISOT.181
     2A(N22),AIN25),AIN26),AIN27),AIN28),A(N29),A(N30),A(N35),A(N36),   BRISOT.182
     3A(NT30),GS,NEQ,NBAND,NUMEL,KLIN)                                  BRISOT.183
      N39=N38+NEQ                                                       BRISOT.184
      N40=N39+NEQ                                                       BRISOT.185
      N41=N40+NEQ                                                       BRISOT.186
      N42=N41+NEQ                                                       BRISOT.187
      N43=N42+NEQ                                                       BRISOT.188
      N44=N43+NEQ                                                       BRISOT.189
      CALL STEP(AIN1),AIN2),AIN3),A(N4),AIN5),A(N6),A(N7),A(N8I,A(N9),  BRISOT.190
     1AIN10),A(N11),AIN12),A(N13),A(N14),AIN15),A(N16),A(N17),A(N18),   BRISOT.191
     2AIN19),AIN20),A(N21),A(N22),A(N23),A(N24I,A(N25),A(N26),A(N27),   BRISOT.192
     3AIN28),AIN29),AIN30),AIN31),A(N32),AIN33),A(N34),A(N35),A(N36),   BRISOT.193
     4AIN37),AINT38),AIN38),A(N39),A(N40),AIN41I,A(N42),AIN43),NELW,NTW,BRISOT.194
     5GS,NUMNP,NEQ,NBAND,RLIN,NUMEL)                                    BRISOT.195
      CALL OUTPUTIAIN1),NUMNP,NUMEL,NEQ,NTW)                            BRISOT.196
      CALL SECONDIS(I3))                                                BRISOT.197
      DO 303 I=1,12                                                     BRISOT.198
  303 S(I)=S(I+11-SII)                                                  BRISOT.199
      TT=0.0                                                            BRISOT.200
      DO 304 I=1,12                                                     BRISOT.201
  304 TT=TT+S(I)                                                        BRISOT.202
      SI13)=TT                                                          BRISOT.203
      WRITE(6,104) S                                                    BRISOT.204
      WRITE(6,105) N44                                                  BRISOT.205
C     ***************                                                   BRISOT.206
C     FORMAT STATEMENT                                                  BRISOT.207
C     ***************                                                   BRISOT.208
    1 FORMAT(12A6/(12I5,F10.4))                                         BRISOT.209
    2 FORMATI15)                                                        BRISOT.210
    3 FORMAT(15)                                                        BRISOT.211
    4 FORMATI16I5)                                                      BRISOT.212
    6 FORMATI3I5)                                                       BRISOT.213
  101 FORMAT(1H1,12A6//                                                 BRISOT.214
     1       * NO. OF NODAL POINTS                          *,I5/       BRISOT.215
     2       * NO. OF ELEMENTS                              *,I5/       BRISOT.216
     3       * NO. OF ELEMENT TYPES                         *,I5/       BRISOT.217
     4       * NONLINEAR OR LINEAR ANALYSIS,0-LINEAR,1-NONLINEAR*,I5/   BRISOT.218
     5       * NO. OF SOIL NATERIAL TYPES                   *,I5/       BRISOT.219
     6       * NO. OF CONCRETE MATERIAL TYPES               *,I5/       BRISOT.220
     7       * NO. OF FRICTION ELEMENT TYPES                *,I5/       BRISOT.221
     8       * NO. OF EXPANSION JOINT TYPES                 *,I5/       BRISOT.222
     9       * NO. OF BOUNDARY ELEMENT TYPES                *,I5/       BRISOT.223
     1       * NO. OF CONCRETE GEOMETRIC PROPERTIES         *,I5/       BRISOT.224
     2       * NO. OF P-M INTERACTION CURVES OF CONCRETE     *,I5/       BRISOT.225
     3       * PLANE STRAIN-0,PLANE STRESS-1                *,I5/       BRISOT.226
     4       * ELEMENT THICKNESS                            *,F10.3)BRISOT.22T
  102 FORMATI*1MATERIAL TYPE NTYPE=*,I5//)                              BRISOT.228
  103 FORMATI* INFORMATIONS OF WALLS=/                                  BRISOT.229
     1       * TOTAL NO. OF WALL=*, I5/                                 BRISOT.230
     2       * NO. OF ELEMENT ON WALL 1,2,...=*,10I5)                   BRISOT.231
  104 FORMAT(*1TIME LOG=*//                                             BRISOT.232
     1       * NODAL POINT INPUT                    *,F8.2//           BRISOT.233
     2       * (INPUT MATERIAL PROPERTIES           *,F8.2//           BRISOT.234
     3       * INPUT ELEMENT DATA                   *,F8.2//           BRISOT.235
     4       * INPUT AND CALCULATE NODAL MASS,LOAD  *,F8.2//           BRISOT.236
     5       * FORM ELASTIC STRESS-STRAIN RELATIONSHIP *,F8.2//        BRISOT.23T
     6       * FORM ELASTIC TOTAL STIFFNESS         *,F8.2//           BRISOT.238
     7       * STATIC SOLUTION OF DISPLACEMENT      *,F8.2//           BRISOT.239
     8       * COMPUTE STRAIN OF SOIL ELEMENT       *,F8.2//           BRISOT.240
     9       * COMPUTE STRESS OF ALL ELEMENT        *,F8.2//           BRISOT.241
     .       * EARTHPRESSURE ON WALL                *,F8.2//           BRISOT.242
     .       * PRINT RESULTS                        *,F8.2//           BRISOT.243
     .       * DYNAMIC SOLUTION                     *,F8.2//           BRISOT.244
     .       * TOTAL SOLUTION TIME                  *,F8.2)            BRISOT.245
  105 FORMAT(* LENGTH OF BLANK COMMON A*,I8)                            BRISOT.246
  106 FORMATI//* NO. OF FREQUENCIES TO BE CALCULATED*,I5/              BRISOT.24T
     1       * THE MODES TO CONTROL THE RAYLEIGH DAMPING*,2I5)          BRISOT.248
      END                                                               BRISOT.249
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```
      SUBROUTINE INPUTJ(ID,X,Y,NUMNP,NEQ)                               INPUTJ.2
C                                                                       INPUTJ.3
C     ***************************************************************INPUTJ.4
C     READ OR GENERATE NODAL POINT DATA                                 INPUTJ.5
C     ***************************************************************INPUTJ.6
C                                                                       INPUTJ.7
      DIMENSION XI1),YI1),IDI3,NUMNP)                                   INPUTJ.8
      WRITE(6,501)                                                      INPUTJ.9
      WRITEI6,502)                                                      INPUTJ.10
      NOLD=0                                                            INPUTJ.11
 1000 CONTINUE                                                          INPUTJ.12
      READ 1,N,(IO(I,N),I=1,3),X(N),Y(N),KN                             INPUTJ.13
      WRITE(6,101) N,(IDII,N),I=1,3),XIN),Y(N),KN                       INPUTJ.14
      IF(NOLD .EO. 0) GO TO 401                                         INPUTJ.15
C                                                                       INPUTJ.16
C     CHECR IF GENERATION IS REQUIRED                                   INPUTJ.17
      IFIRN .EO. 0) GO  TO 401                                          INPUTJ.18
C                                                                       INPUTJ.19
C     NUM=NO. OF INTERVALS BETWEEN INPUT NODE                           INPUTJ.20
C     NUMN=NO. OF NODES TO BE GENERATED                                 INPUTJ.21
C     DX,DY, THE LENGTH OF INTERVAL                                     INPUTJ.22
      NUM=N-NOLD                                                        INPUTJ.23
      NUMN=NUM-1                                                        INPUTJ.24
      IF(NUMN .LT. 1) GO TO 401                                         INPUTJ.25
      XNUM=NUM                                                          INPUTJ.26
      DX=(X(N)-X(NOLD))I/XNUM                                           INPUTJ.2T
      DY=(Y(N)-Y(NOLD))/XNUM                                            INPUTJ.28
C                                                                       INPUTJ.29
C     GENERATE NEW NODAL POINT                                          INPUTJ.30
      R=NOLD                                                            INPUTJ.31
      DO 301 J=1,NUMN                                                   INPUTJ.32
      KK=R                                                              INPUTJ.33
      K=K+1                                                             INPUTJ.34
      XIK)=XIRR)+DX                                                     INPUTJ.35
      Y(R)=Y(KK)+DY                                                     INPUTJ.36
      DO 301 I=1,3                                                      INPUTJ.37
      ID(I,K)=IO(I,KR)                                                  INPUTJ.38
  301 CONTINUE                                                          INPUTJ.39
  401 CONTINUE                                                          INPUTJ.40
      NOLD=N                                                            INPUTJ.41
      IF(N .NE. NUMNP) GO TO 1000                                       INPUTJ.42
C                                                                       INPUTJ.43
C     PRINT ALL NODAL POINT DATA                                        INPUTJ.44
      WRITE(6,503)                                                      INPUTJ.45
      WRITEI6,502)                                                      INPUTJ.46
      WRITEI6,201)IN,(IOII,N),I=1,3),X(N),YIN),N=1,NUMNP)               INPUTJ.47
C                                                                       INPUTJ.48
C     CALCULATE THE EQUATION NUMBERS FOR EVERY DEGREE OF FREEDOM        INPUTJ.49
      NEQ=0                                                             INPUTJ.50
      DO 302 N=I,NUMNP                                                  INPUTJ.51
      DO 302 I=1,3                                                      INPUTJ.52
      IF(IOII,N)-1) 402,403,403                                         INPUTJ.53
  402 CONTINUE                                                          INPUTJ.54
      NEQ=NEQ+1                                                         INPUTJ.55
      ID(I,N)=NEQ                                                       INPUTJ.56
      GO TO 302                                                         INPUTJ.57
```

```
  403 IO(I,N)=0                                                          INPUTJ.58
  302 CONTINUE                                                           INPUTJ.59
C                                                                        INPUTJ.60
C     WRITE EQUATION NUMBERS                                             INPUTJ.61
      WRITE(6,202) (N,(IO(I,N),I=1,3),N=1,NUMNP)                         INPUTJ.62
      RETURN                                                             INPUTJ.63
    1 FORMAT(415,2F10.2,I5)                                              INPUTJ.64
  101 FORMAT(415,14X,2F10.2,IT)                                          INPUTJ.65
  201 FORMAT(415,14X,2F10.2)                                             INPUTJ.66
  501 FORMAT(23H NODAL POINT INPUT DATA)                                 INPUTJ.67
  202 FORMAT(//17H EQUATION NUMBERS/                                     INPUTJ.68
     1       20H    N     X     Y     ZZ/(4I5))                         INPUTJ.69
  502 FORMAT(9HONODE,3X,24HBOUNDARY CONDITION CODES,11X,                 INPUTJ.70
     1       23HNODAL POINT COORDINATES/                                 INPUTJ.T1
     2       7H NUMBER,2X,1HX,4X,1HY,4X,2HZZ,                           INPUTJ.T2
     3       22X,1HX, 9X,1HY,4X,2HKN//)                                 INPUTJ.T3
  503 FORMAT(* GENERATED NODAL DATA*)                                    INPUTJ.T4
      END                                                                INPUTJ.T5
```

```
      SUBROUTINE MATPRO(NTYPE,PARASO,PARACO,PARAFR,PARAEX,PARABO,        MATPRO.2
     1COPROP,K2S,CNP)                                                    MATPRO.3
C                                                                        MATPRO.4
C*************************************************************************MATPRO.5
C     INPUT MATERIAL PROPERTIES,BEAM,COLUMN GEOMETRIC PROPERTY           MATPRO.6
C*************************************************************************MATPRO.7
C                                                                        MATPRO.8
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NIMTCV,THICKMATPRO.9
     1,NPLAN                                                             MATPRO.10
      DIMENSION PARASO(8,1),PARACO(5,1),PARAFR(4,1),PARAEX(4,1),         MATPRO.11
     1          PARABO(2,1),COPROP(3,1),K2S(20,1),CNP(9,1)               MATPRO.12
      COMMON/ELPAR/NUMNP,NUREL,NEQ,MBAND,KLIN                            MATPRO.13
      REAL K2S                                                           MATPRO.14
      WRITE(6,501)                                                       MATPRO.15
      GO TO (401,402,403,404,405),NTYPE                                  MATPRO.16
  401 CONTINUE                                                           MATPRO.17
C                                                                        MATPRO.18
C     READ IN SOIL PROPERTY DATA                                         MATPRO.19
C                                                                        MATPRO.20
      DO 306 I=1,NUMATS                                                  MATPRO.21
      READ 2, N, (PARASO(J,N),J=1,8)                                     MATPRO.22
  306 CONTINUE                                                           MATPRO.23
      WRITE(6,502)                                                       MATPRO.24
      WRITE(6,102) (N,(PARASO(J,N),J=1,8),N=1,NUMATS)                    MATPRO.25
      IF(KLIN .EQ. 0) GO TO 312                                          MATPRO.26
      WRITE(6,503)                                                       MATPRO.27
      DO 301 I=1,NUMATS                                                  MATPRO.28
      READ 2, N,(K2S(J,N),J=1,20)                                        MATPRO.29
      WRITE(6,103) N,(K2S(J,N),J=1,20)                                   MATPRO.30
  301 CONTINUE                                                           MATPRO.31
      GO TO 312                                                          MATPRO.32
C                                                                        MATPRO.33
C     READ IN CONCRETE PROPERTY DATA                                     MATPRO.34
C                                                                        MATPRO.35
  402 CONTINUE                                                           MATPRO.36
      DO 307 I=1,NUMATC                                                  MATPRO.3T
      READ 2,N,(PARACO(J,N),J=1,5)                                       MATPRO.38
  307 CONTINUE                                                           MATPRO.39
C                                                                        MATPRO.40
C     READ IN BEAM,COLUMN GEOMETRIC DATA AND INTERACTION CURVE           MATPRO.41
C                                                                        MATPRO.42
      WRITE(6,505)                                                       MATPRO.43
      WRITE(6,105) (N,(PARACO(J,N),J=1,5),N=1,NUMATC)                    MATPRO.44
      WRITE(6,50T)                                                       MATPRO.45
      DO 308 I=1,NUMGE                                                   MATPRO.46
      READ 2,N,(COPROPIJ,N),J=1,3)                                       MATPRO.4T
      WRITE(6,10T) N,(COPROP(J,N),J=1,3)                                 MATPRO.48
  308 CONTINUE                                                           MATPRO.49
      IF(KLIN .EQ. 0) GO TO 312                                          MATPRO.50
      IF(NINTCV .EQ. 0) GO TO 312                                        MATPRO.51
      WRITE(6,508)                                                       MATPRO.52
      DO 302 I=1,NINTCV                                                  MATPRO.53
      READ 3,N,(CNP(J,N),J=1,9)                                          MATPRO.54
      WRITE(6,108) N,(CNP(J,N),J=1,9)                                    MATPRO.55
  302 CONTINUE                                                           MATPRO.56
```

```
      GO TO 312                                                          MATPRO.57
C                                                                        MATPRO.58
C     READ IN FRICTIONAL ELEMENT PROPERTY                                MATPRO.59
C                                                                        MATPRO.60
  403 CONTINUE                                                           MATPRO.61
      DO 309 I=1,NUMATF                                                  MATPRO.62
      READ 1,N,(PARAFR(J,N),J=1,4)                                       MATPRO.63
  309 CONTINUE                                                           MATPRO.64
      WRITE(6,510)                                                       MATPRO.65
      WRITE(6,110)(N,(PARAPR(J,N),J=1,4),N=1,NUMATP)                     MATPRO.66
      GO TO 312                                                          MATPRO.67
C                                                                        MATPRO.68
C     READ EXPANSION JOINT DATA                                          MATPRO.69
C                                                                        MATPRO.70
  404 CONTINUE                                                           MATPRO.71
      DO 310 I=1,NUMATE                                                  MATPRO.72
      READ 1,N,(PARAEX(J,N),J=1,4)                                       MATPRO.73
  310 CONTINUE                                                           MATPRO.74
      WRITE(6,512)                                                       MATPRO.75
      WRITE(6,112) (N,(PARAEXIJ,N),J=1,4),N=1,NUMATE)                    MATPRO.76
      GO TO 312                                                          MATPRO.77
C                                                                        MATPRO.T8
C     READ IN BOUNDARY ELEMENT DATA                                      MATPRO.79
C                                                                        MATPRO.80
  405 CONTINUE                                                           MATPRO.81
      DO 311 I=1,NUMATB                                                  MATPRO.82
      READ 2,N,(PARABO(J,N),J=1,2)                                       MATPRO.83
  311 CONTINUE                                                           MATPRO.84
      WRITE(6,514)                                                       MATPRO.85
      WRITE(6,114)(N,(PARABO(J,N),J=1,2),N=1,NUMATB)                     MATPRO.86
  312 CONTINUE                                                           MATPRO.87
      RETURN                                                             MATPRO.88
C                                                                        MATPRO.89
C     FORMAT STATEMENT                                                   MATPRO.90
C                                                                        MATPRO.91
    1 FORMAT(I10/(4E10.2))                                               MATPRO.92
    2 FORMAT(I10/(8F10.3))                                               MATPRO.93
    3 FORMAT(I10/(9F8.3))                                                MATPRO.94
  102 FORMAT(I2,8F10.3)                                                  MATPRO.95
  103 FORMAT(I2,2F10.3/(2X,2F10.3))                                      MATPRO.96
  105 FORMAT(I2,5F10.3)                                                  MATPRO.97
  107 FORMAT(1X,I2,3F10.1)                                               MATPRO.98
  108 FORMAT(I2,10X,F10.3,10X,F10.3,10X,F10.3/                           MATPRO.99
     1I12X,F10.3,10X,F10.3,10X,F10.3))                                   MATPRO.100
  110 FORMAT(I2,4E10.2)                                                  MATPRO.101
  112 FORMAT(I2,4E10.2)                                                  MATPRO.102
  114 FORMAT(I2,2F10.3)                                                  MATPRO.103
  501 FORMAT(* MATERIAL PROPERTY,BEAM AND COLUMN GEOMETRICAL PROPERTY DAMATPRO.104
     'TA*///)                                                            MATPRO.105
  502 FORMAT(* SOIL PROPERTY DATA*//                                     MATPRO.106
     1       * ELASTIC SHEAR MODULUS=G1   KSI*/                        MATPRO.107
     2       * PLASTIC SHEAR MODULUS=G2   KSI*/                        MATPRO.108
     3       * POISSON,S RATIO      =NU      */                        MATPRO.109
     4       * COHESION OF CLAY       =C  LB/INCH*/                    MATPRO.110
     5       * FRICTIONAL ANGLE      =PHI*/                           MATPRO.111
     6       * YIELD SHEAR STRAIN   =GAMMAY*/                         MATPRO.112
     7      * MASS DENSITY      =RHO LB-SEC.SQ/FT/CU.FT*/              MATPRO.113
     8       * UNIT WEIGHT OF SOIL  =WT LB/CU.FT*/                    MATPRO.114
     92H N,8X,2HG1,8X,2HG2,8X,2HNU,9X,1HC,7X,3HPHI,5X,                 MATPRO.115
     .5HGAMMA,7X,3HRHO,8X,2HWT//)                                      MATPRO.116
  503 FORMAT(* SHEAR MODULUS CURVE DATA *//                            MATPRO.11T
     1       * MATERIAL NO.=N*/                                        MATPRO.118
     2       * COEFFICIENT OF TANGENT SHEAR MODULUS=K2S*/               MATPRO.119
     3       * SHEAR STRAIN=GAMMAY */                                  MATPRO.120
     42H N,7X,3HK2S,4X,6HGAMMAY//)                                     MATPRO.121
  505 FORMAT(* CONCRETE PROPERTY DATA *//                              MATPRO.122
     1       * ELASTIC MODULUS=E1  KSI*/                               MATPRO.123
     2       * PLASTIC MODULUS=E2   KSI*/                              MATPRO.124
     3       * POISSION,S RATIO=NU*/                                   MATPRO.125
     4      * MASS DENSITY=RHO LB-SEC.SO/FT/CU.PT*/                    MATPRO.126
     5       * UNIT WEIGHT=WT  LB/CU.FT*/                              MATPRO.127
     62H N,8X,2HE1,8X,2HE2,8X,2HNU,7X,3HRHO,8X,2HWT//)                 MATPRO.128
  507 FORMAT(* GEOMETRIC PROPERTY OF BEAN,COLUMN *//                   MATPRO.129
     1       * GEOMETRIC PROPERTY NUMBER=N */                          MATPRO.130
     2       * AXIAL AREA=A  SO.INCHES*/                               MATPRO.131
     3       * SHEAR AREA=AV  SO. (INCH*/                              MATPRO.132
     4       * MOMENT OF INERTIA=I INCH.4*//                           MATPRO.133
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     52H N,9X,1HA,8X,2HAV,9X,1HI//)                                    MATPRO.134
 500 FORMAT* AXIAL LOAD,MOMENT INTERACTION CURVE*//                    MATPRO.135
     12H N,3X,12HECCENTRICITY,4X,16HAXIAL LOAD  KIPS,TX,               MATPRO.136
     213HMOMENT   K-IN//)                                              MATPRO.137
 510 FORMAT* FRICTION ELEMENT DATA*//                                  MATPRO.138
     1       * SHEAR STIFF=KS  KSI*/                                   MATPRO.139
     2       * NORMAL STIFF =KN  KSI*/                                 MATPRO.140
     3       * FRICTION COEFFICIENT=U*/                                MATPRO.141
     4       * ANGLE OF WALL TO VERTICAL AXIS=THETA*//                 MATPRO.142
     52H N,8X,2HKS,8X,2HKN,9X,1HU,5X,5HTHETA//I                        MATPRO.143
 512 FORMAT* EXPANSION JOINT DATA *//                                  MATPRO.144
     1       * GAP AT JOINT=GAP  INCH*/                                MATPRO.145
     2       * SEAT FOR ALLOWING SLIDING=SEAT  INCH*/                  MATPRO.146
     3       * FRICTIONAL COEFFICIENT=U*//                             MATPRO.147
     4       * LEFT OR RIGHT END INDICATOR=IND*/                       MATPRO.148
     52H N,TX,3HGAP,6X,4HSEAT,9X,1HU,TX,3HIND//)                       MATPRO.149
 514 FORMAT* BOUNDARY ELEMENT DATA*//                                  MATPRO.150
     1       * ELASTIC MODULUS=EL  KSI*/                               MATPRO.151
     2       * YIELD STRESS=FY  KSI*/                                  MATPRO.152
     32H N,8X,2HEL,8X,2HFY//)                                          MATPRO.153
     END                                                               MATPRO.154
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      SUBROUTINE ELDATA(IIO,IX,IBC,MBAND,NUMEL)                        ELDATA.2
C                                                                      ELDATA.3
C     ****************************************************************ELDATA.4
C     IDENTIFY THE ELEMENT NODAL POINT,ELEMENT TYPE,MATERIAL TYPE,     ELDATA.5
C     BEAM GEOMETRIC PROPERTY NO.,END RELEASE CODE                     ELDATA.6
C     ****************************************************************ELDATA.7
C                                                                      ELDATA.8
      DIMENSION IOI3,1),IXI6,NUMEL),IBC(4,NUMEL),LM(12I                ELDATA.9
      DIMENSION IDEI10)                                                ELDATA.10
      WRITEI6,501)                                                     ELDATA.11
      N=0                                                              ELDATA.12
      MBAND=0                                                          ELDATA.13
      DO 301 I=1,10                                                    ELDATA.14
      IDEIII=0                                                         ELDATA.15
  301 CONTINUE                                                         ELDATA.16
      DO 351 I=1,4                                                     ELDATA.17
      DO 352 J=1,NUMEL                                                 ELDATA.18
  352 IBCII,JI=0                                                       ELDATA.19
  351 CONTINUE                                                         ELDATA.20
C                                                                      ELDATA.21
C     READ IN ELEMENT DATA                                             ELDATA.22
 1000 READ 1,N,(IDEII),I=1,10)                                         ELDATA.23
 2000 N=N+1                                                            ELDATA.24
      IFIN .EQ. NI GO TO 401                                           ELDATA.25
C                                                                      ELDATA.26
C     ELEMENT DATA GENERATEION NEEDED                                  ELDATA.27
      DO 303 I=1,4                                                     ELDATA.28
      IXII,NI=IXII,N-1)+1                                              ELDATA.29
      NODE=IXII,NI                                                     ELDATA.30
      JJJ=3*I                                                          ELDATA.31
      JJ=JJJ-1                                                         ELDATA.32
      J=JJ-1                                                           ELDATA.33
      LMIJJJ)=IOI3,NODE)                                               ELDATA.34
      LM(JJ)=IOI2,NODE)                                                ELDATA.35
      LMIJ)=IOI1,NODEI                                                 ELDATA.36
  303 CONTINUE                                                         ELDATA.37
      MAX=0                                                            ELDATA.38
      MIN=10000                                                        ELDATA.39
      DO 355 L=I,12                                                    ELDATA.40
      IFILMILI .EQ. 0) GO TO 355                                       ELDATA.41
      IFILMIL) .GT. MAX) MAX=LMIL)                                     ELDATA.42
      IFILMIL) .LT. MIN) MIN=LMIL)                                     ELDATA.43
  355 CONTINUE                                                         ELDATA.44
      IFIMAX .EQ. 0) MIN=1                                             ELDATA.45
      MB=MAX-MIN+1                                                     ELDATA.46
      IFIMB .GT. MBAND) MBAND=MB                                       ELDATA.47
      IX(5,N)=IX(5,N-1)                                                ELDATA.48
      IX(6,N)=IX(6,N-1)                                                ELDATA.49
      IFIIDEIT) .NE. 0) GO TO 406                                      ELDATA.50
      GO TO 402                                                        ELDATA.51
  406 CONTINUE                                                         ELDATA.52
      DO 306 I=1,4                                                     ELDATA.53
      IBCII,NI=IBCII,N-1)                                              ELDATA.54
  306 CONTINUE                                                         ELDATA.55
      GO TO 403                                                        ELDATA.56
C                                                                      ELDATA.57
  401 DO 304 I=1,6                                                     ELDATA.58
      IXII,NI=IDEII)                                                   ELDATA.59
  304 CONTINUE                                                         ELDATA.60
      DO 354 I=1,4                                                     ELDATA.61
      NODE=IXII,NI                                                     ELDATA.62
      JJJ=3*I                                                          ELDATA.63
      JJ=JJJ-1                                                         ELDATA.64
      J=JJ-1                                                           ELDATA.65
      LMIJJJ)=IOI3,NODE)                                               ELDATA.66
      LMIJJ)=IOI2,NODE)                                                ELDATA.67
      LMIJI=IOI1,NODE)                                                 ELDATA.68
  354 CONTINUE                                                         ELDATA.69
      MIN=10000                                                        ELDATA.70
      MAX=0                                                            ELDATA.71
      DO 353 L=1,12                                                    ELDATA.72
      IFILMILI .EQ. 0I GO TO 353                                       ELDATA.73
      IFILMILI .GT. MAXI MAX=LMILI                                     ELDATA.74
      IFILMIL) .LT. MIN) MIN=LMIL)                                     ELDATA.75
  353 CONTINUE                                                         ELDATA.76
      IFIMAX .EQ. 0I MIN=1                                             ELDATA.77
      MB=MAX-MIN+1                                                     ELDATA.78
      IF(MB .GT. MBANDI MBAND=MB                                       ELDATA.79
C                                                                      ELDATA.80
C     NOT BEAM OR COLUMN                                               ELDATA.81
      IFIIDEITI .EQ. 0I GO TO 402                                      ELDATA.82
C                                                                      ELDATA.83
C     BEAM OR COLUMN ELEMENT                                           ELDATA.84
      DO 305 I=1,4                                                     ELDATA.85
      IBCII,NI=IDE(I+6I                                                ELDATA.86
  305 CONTINUE                                                         ELDATA.87
      GO TO 403                                                        ELDATA.88
  402 CONTINUE                                                         ELDATA.89
      WRITEI6,101I N,(IXII,NI,I=1,6I,MB                                ELDATA.90
      GO TO 404                                                        ELDATA.91
  403 CONTINUE                                                         ELDATA.92
      WRITEI6,102I N,IIXII,NI,I=1,6I,IIBC(J,N),J=I,4I,MB               ELDATA.93
  404 IFIN .EQ. NUMEL) GO TO 405                                       ELDATA.94
      IFIN .EQ. NI GO TO 1000                                          ELDATA.95
      GO TO 2000                                                       ELDATA.96
  405 CONTINUE                                                         ELDATA.97
      RETURN                                                           ELDATA.98
    1 FORMATIIIIS)                                                     ELDATA.99
  101 FORMATI9X,I3,4I4,9X,I4,9X,I4,59X,I4I                             ELDATA.100
  102 FORMATI9X,I3,4I4,9X,I4,9X,I4,17X,I4,12X,2I4,TX,I2,9X,I4I         ELDATA.101
  501 FORMAT(54HIELEMENT NO.   I   J   K   L ELEMENT TYPE MATERIAL NO.,3ELDATA.102
     1X,60HGEOMETRIC PROPERTY   END RELEASE I   J   MINTCV   BAND WIDTHIELDATA.103
      END                                                              ELDATA.104
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      SUBROUTINE LOAD(ID,X,Y,PARASD,PARACD,COPROP,IX,IBC,                LOAD.2
     1SLV,DLX,DLY,TMASS,TLOAD,NUMEL,NEQ)                                 LOAD.3
C                                                                        LOAD.4
C     ***************************************************************** LOAD.5
C     CALCULATE STATIC LOAD VECTOR-SLV,                                  LOAD.6
C     DYNAMIC LOAD IN X DIRECTION-DLX                                    LOAD.7
C     DYNAMIC LOAD VECTOR IN Y DIRECTION-DLY                             LOAD.8
C     ***************************************************************** LOAD.9
C                                                                        LOAD.10
      DIMENSION ID(3,1),X(1),Y(1I,PARASD(8,1),PARACD(9,1),COPROP(3,1),   LOAD.11
     1IX(6,1I,IBC(4,1I                                                   LOAD.12
      DIMENSION XX(4),YY(4I,LM(8)                                        LOAD.13
      DIMENSION SLV(NEQ),DLX(NEQ),DLY(NEQ),TMASS(NEQ),TLOAD(NEQI         LOAD.14
C                                                                        LOAD.15
C     INITIZATION                                                        LOAD.16
      DO 301 I=1,NEQ                                                     LOAD.17
      SLV(I)=0.0                                                         LOAD.18
      DLX(I)=0.0                                                         LOAD.19
      DLY(I)=0.0                                                         LOAD.20
  301 CONTINUE                                                           LOAD.21
C                                                                        LOAD.22
C     CALCULATE LOAD ELEMENT BY ELEMENT                                  LOAD.23
      DO 302 N=1,NUMEL                                                   LOAD.24
C                                                                        LOAD.25
C     DETERMINE WHICH ELEMENT TYPE                                       LOAD.26
      NTYPE=IX(5,N)                                                      LOAD.27
      GO TO (401,402,403,403,403I,NTYPE                                  LOAD.28
C                                                                        LOAD.29
C     TYPE 1,SOIL ELEMENT                                                LOAD.30
  401 CONTINUE                                                           LOAD.31
      DO 303 J=1,4                                                       LOAD.32
      NODE=IX(J,N)                                                       LOAD.33
      JJ=J+J                                                             LOAD.34
      LM(JJI=ID(2,NODE)                                                  LOAD.35
      LM(JJ-1)=ID(1,NODEI                                                LOAD.36
      XX(JI=X(NODE)                                                      LOAD.37
      YY(J)=Y(NODE)                                                      LOAD.38
  303 CONTINUE                                                           LOAD.39
      MATYPE=IX(6,N)                                                     LOAD.40
      CALL FSOIL(XX,YY,AMASS,WT,PARASD(1,MATYPEI,IX(1,NI)                LOAD.41
      DO 304 J=1,4                                                       LOAD.42
      JJ=J+J                                                             LOAD.43
      IT=LM(JJI                                                          LOAD.44
      ITT=LM(JJ-1)                                                       LOAD.45
      IF(IT .EQ. 0) GO TO 404                                            LOAD.46
      SLV(ITI=-WT+SLV(IT)                                                LOAD.47
      DLX(IT)=0.0+DLX(IT)                                                LOAD.48
      OLY(ITP=AMASS+DLY(IT)                                              LOAD.49
  404 CONTINUE                                                           LOAD.50
      IF(ITT .EQ. 0) GO TO 304                                           LOAD.51
      SLV(ITTI=0.0+SLV(ITT)                                              LOAD.52
      OLX(ITTI=AMASS+DLX(ITT)                                            LOAD.53
      DLY(ITT)=0.0+DLY(ITT)                                              LOAD.54
  304 CONTINUE                                                           LOAD.55
      GO TO 403                                                          LOAD.56
C                                                                        LOAD.57
C     TYPE 2,CONCRETE ELEMENT                                            LOAD.58
  402 CONTINUE                                                           LOAD.59
      DO 305 J=1,2                                                       LOAD.60
      JJ=3*J                                                             LOAD.61
      NODE=IX(J,N)                                                       LOAD.62
      LM(JJ)=ID(3,NODE)                                                  LOAD.63
      LM(JJ-1)=ID(2,NODE)                                                LOAD.64
      LM(JJ-2)=ID(1,NODE)                                                LOAD.65
      XX(J)=X(NODE)                                                      LOAD.66
      YY(J)=Y(NODE)                                                      LOAD.67
  305 CONTINUE                                                           LOAD.68
      MATYPE=IX(6,N)                                                     LOAD.69
      NG=IBC(1,N)                                                        LOAD.70
      AXA=COPROP(1,NG)                                                   LOAD.71
      WT=AXA*PARACD(5,MATYPE)/144.0                                      LOAD.72
      AMASS=AXA*PARACD(4,MATYPE)/144.0                                   LOAD.73
      CALL FBECOL(XX,YY,AMASS,WT,FEN)                                    LOAD.74
      DO 306 J=1,2                                                       LOAD.75
      JJ=3*J                                                             LOAD.76
      IT=LM(JJ)                                                          LOAD.77
      ITT=LM(JJ-1)                                                       LOAD.78
      (TTT=LM(JJ-2)                                                      LOAD.79
      IF(IT .EQ. 0) GO TO 405                                            LOAD.80
      SLV(IT)=(-1)**(J)*FEN+SLV(IT)                                      LOAD.81
      DLY((T)=0.0+DLY((T)                                                LOAD.82
      OLX(IT)=0.0+OLX(IT)                                                LOAD.83
  405 CONTINUE                                                           LOAD.84
      IF((TT .EQ. 0) GO TO 406                                           LOAD.85
      SLV(ITT)=-WT+SLV(ITT)                                              LOAD.86
      OLX(ITT)=0.0+DLX(ITT)                                              LOAD.87
      DLY(ITT)=AMASS+DLY(ITT)                                            LOAD.88
  406 CONTINUE                                                           LOAD.89
      IP(ITTT .EQ. 0) GO TO 306                                          LOAD.90
      SLV(ITTT)=0.0+SLV(ITTT)                                            LOAD.91
      OLX(ITTT)=AMASS+DLX(ITTT)                                          LOAD.92
      DLY(ITTT)=0.0+DLY(ITTT)                                            LOAD.93
  306 CONTINUE                                                           LOAD.94
  403 CONTINUE                                                           LOAD.95
  302 CONTINUE                                                           LOAD.96
C                                                                        LOAD.97
C     ADD UP CONCENTRATED MASS,OR/AND, LOAD                              LOAD.98
      G=386.07                                                           LOAD.99
      CALL INCML(IO,TMASS,TLOADI                                         LOAD.100
      DO 307 I=1,NEQ                                                     LOAD.101
      SLV(I)=SLV(I)+TMASS(I)*G+TLOAD(II                                  LOAD.102
      DLX(I)=DLX(I)+TMASS(I)                                             LOAD.103
      OLY(I)=DLY(I)+TMASS(I)                                             LOAD.104
  307 CONTINUE                                                           LOAD.105
      WRITE(6,501I                                                       LOAD.106
      WRITE(6,101)(SLV(I),DLX(II,DLY(I),I=1,NEQ)                         LOAD.107
C                                                                        LOAD.108
C     PUT MASS MATRIX INTO TAPE4,KIP,INCH,SEC                            LOAD.109
      DO 308 I=1,NEQ                                                     LOAD.110
  308 TMASS(I)=DLX(II+DLY(I)                                             LOAD.111
      WRITE(4) TMASS                                                     LOAD.112
      RETURN                                                             LOAD.113
  101 FORMAT(F10.3,2F10.6)                                               LOAD.114
  501 FORMAT(* LOAD VECTOR *//                                           LOAD.115
     1*       SLV*,*       DLX*,*       OLY*)                          LOAD.116
      END                                                                LOAD.117
```

```
      SUBROUTINE FSOIL(XX,YY,AMASS,WT,FARASO,IX)                        FSOIL.2
C                                                                       FSOIL.3
C     ****************************************************************FSOIL.4
C     CALCULATE LUMP MASS OF SOIL ELEMENT                               FSOIL.5
C     ****************************************************************FSOIL.6
C                                                                       FSOIL.7
      COMMON/WATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,MINTCV,THICKFSOIL.8
     1,NPLAN                                                            FSOIL.9
      DIMENSION PARASO(8),XX(4),YY(4),IX(6)                             FSOIL.10
      Y24=YY(2)-YY(4)                                                   FSOIL.11
      Y31=YY(3)-YY(1)                                                   FSOIL.12
      Y42=-Y24                                                          FSOIL.13
      Y13=-Y31                                                          FSOIL.14
      AREA=XX(1)*Y24+XX(2)*Y31+XX(3)*Y42+XX(4)*Y13                      FSOIL.15
      AREA=AREA/2.0                                                     FSOIL.16
C                                                                       FSOIL.17
C     TOTAL MASS,AND WEIGHT                                             FSOIL.18
      RHO=PARASO(7)                                                     FSOIL.19
      W=PARASO(8)                                                       FSOIL.20
      TMASS=RHO*AREA*THICK                                              FSOIL.21
      WT=W*AREA*THICK                                                   FSOIL.22
C                                                                       FSOIL.23
C     LUMPED MASS,WEIGHT AT NODE,FOR QUADLATERAL ELEMENT                FSOIL.24
      IF(IX(3) .EQ. IX(4)) GO TO 401                                    FSOIL.25
      AMASS=TMASS/48000.0                                               FSOIL.26
      WT=WT/4000.0                                                      FSOIL.27
      GO TO 402                                                         FSOIL.28
  401 CONTINUE                                                          FSOIL.29
C                                                                       FSOIL.30
C     TRIANGULAR ELEMENT                                                FSOIL.31
      AMASS=TMASS/36000.0                                               FSOIL.32
      WT=WT/3000.0                                                      FSOIL.33
  402 CONTINUE                                                          FSOIL.34
      RETURN                                                            FSOIL.35
      END                                                               FSOIL.36
```

```
      SUBROUTINE FBECOL(XX,YY,AMASS,WT,FEN)                             FBECOL.2
C                                                                       FBECOL.3
C     ****************************************************************FBECOL.4
C     CALCULATE THE DEAD LOAD AND F.E.N. OF CONCRETE                    FBECOL.5
C     ****************************************************************FBECOL.6
C                                                                       FBECOL.7
      DIMENSION XX(2),YY(2)                                             FBECOL.8
C                                                                       FBECOL.9
C     LENGTH=BL                                                         FBECOL.10
      HL=XX(2)-XX(1)                                                    FBECOL.11
      VL=YY(2)-YY(1)                                                    FBECOL.12
      BL=SQRT(HL**2+VL**2)                                              FBECOL.13
      BL=ABS(BL)                                                        FBECOL.14
      H=ABS(HL)                                                         FBECOL.15
      FEN=HL**2*WT/12.0                                                 FBECOL.16
      WT=BL*WT/2.0                                                      FBECOL.17
      AMASS=BL*AMASS/2.0                                                FBECOL.18
      FEN=FEN*12.0/1000.0                                               FBECOL.19
      WT=WT/1000.0                                                      FBECOL.20
      AMASS=AMASS/12000.0                                               FBECOL.21
      RETURN                                                            FBECOL.22
      END                                                               FBECOL.23
```

```
      SUBROUTINE INCNL(IO,TMASS,TLOAD)                                  INCNL.2
C                                                                       INCNL.3
C     ****************************************************************INCNL.4
C     INPUT CONCENTRATED MASS OR LOAD                                   INCNL.5
C     ****************************************************************INCNL.6
C                                                                       INCNL.7
      DIMENSION IO(3,1),TMASS(1),TLOAD(1),RN(3),RL(3)                   INCNL.8
      COMMON/ELPAR/NUMNP,NUMEL,NEQ,NBAND,KLIN                           INCNL.9
      WRITE(6,501)                                                      INCNL.10
      DO 301 I=1,NEQ                                                    INCNL.11
      TMASS(I)=0.0                                                      INCNL.12
      TLOAD(I)=0.0                                                      INCNL.13
  301 CONTINUE                                                          INCNL.14
C                                                                       INCNL.15
C     INPUT JOINT MASS AND LOAD                                         INCNL.16
      DO 302 NN=1,NUMNP                                                 INCNL.17
      READ (5,1)N,(RN(J),J=1,3),(RL(J),J=1,3)                          INCNL.18
      IF(N .EQ. 0) GO TO 304                                            INCNL.19
      WRITE(6,101) N,RN,RL                                              INCNL.20
      IF( N .GT. NUMNP) GO TO 304                                       INCNL.21
      DO 303 J=1,3                                                      INCNL.22
      II=IO(J,N)                                                        INCNL.23
      IF(II .EQ. 0) GO TO 303                                           INCNL.24
      TMASS(II)=RN(J)                                                   INCNL.25
      TLOAD(II)=RL(J)                                                   INCNL.26
      TMASS(II)=TMASS(II)/12000.0                                       INCNL.27
      TLOAD(II)=TLOAD(II)/1000.0                                        INCNL.28
  303 CONTINUE                                                          INCNL.29
  302 CONTINUE                                                          INCNL.30
  304 CONTINUE                                                          INCNL.31
      RETURN                                                            INCNL.32
    1 FORMAT(I10,6F10.3)                                                INCNL.33
  101 FORMAT(I5,6F10.3)                                                 INCNL.34
  501 FORMAT(* INPUT DATA OF CONCENTRATED MASS AND LOAD IN LB,FT,S*//   INCNL.35
     15H NODE,4X,6HMASS-X,4X,6HMASS-Y,3X,7HMASS-ZZ,                     INCNL.36
     26HLOAD-X,4X,6HLOAD-Y,3X,7HLOAD-ZZ//)                              INCNL.37
      END                                                               INCNL.38
```

```
      SUBROUTINE ESGEPSIX,Y,PARASO,PARACO,PARAFR,PARAEX,PARABO,COPROP,  ESGEPS.2
     1                  IX,IBC,C,BCL,O1,O2,O3,D4,O5,NUMATS,NUMATC,      ESGEPS.3
     2                  NUMATF,NUMATE,NUMATB,NUMGE,NPLAN)               ESGEPS.4
C                                                                       ESGEPS.5
C     ****************************************************************ESGEPS.6
C     CALCULATE ELASTIC STRESS-STRAIN,OR ELEMENT FORCE-DEFORMATION RELATESGEPS.7
C     ****************************************************************ESGEPS.8
C                                                                       ESGEPS.9
      DIMENSION PARASO(8,1),PARACO(5,1),PARAFR(4,1),PARAEX(4,1),        ESGEPS.10
     1          PARABO(2,1),COPROP(3,1),IX(6,1),IBC(4,1),C(5,1),       ESGEPS.11
     2          O1)5,1),O2(5,NUMATC,1),O3)5,1),O4(5,1),O5(5,1),        ESGEPS.12
     3          X)1),Y(1),BCL(1),XX(2),YY(2)                           ESGEPS.13
      COMMON/ELPAR/NUMNP,NUMEL,NEQ,NBAND,KLIN                           ESGEPS.14
C                                                                       ESGEPS.15
C     INITILIZATION                                                     ESGEPS.16
      DO 301 I=1,5                                                      ESGEPS.17
      DO 302 J=1,NUMEL                                                  ESGEPS.18
      C(I,J)=0.0                                                        ESGEPS.19
  302 CONTINUE                                                          ESGEPS.20
      DO 303 J=1,NUMATS                                                 ESGEPS.21
      O1)I,J)=0.0                                                       ESGEFS.22
  303 CONTINUE                                                          ESGEPS.23
      DO 304 J=1,NUMATC                                                 ESGEPS.24
      DO 305 K=1,NUMGE                                                  ESGEPS.25
      O2)I,J,K)=0.0                                                     ESGEPS.26
  305 CONTINUE                                                          ESGEPS.27
  304 CONTINUE                                                          ESGEFS.28
      DO 306 J=1,NUMATF                                                 ESGEFS.29
      O3)I,J)=0.0                                                       ESGEFS.30
  306 CONTINUE                                                          ESGEPS.31
      DO 307 J=1,NUMATE                                                 ESGEFS.32
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      D4I1,J)=0.0                                                          ESGEPS.33
  307 CONTINUE                                                             ESGEPS.34
      DO 308 J=1,NUMATB                                                    ESGEPS.35
      05I1,J)=0.0                                                          ESGEPS.36
  308 CONTINUE                                                             ESGEPS.37
  301 CONTINUE                                                             ESGEPS.38
C                                                                          ESGEPS.39
C     FORM BASIC MATERIAL CONSTANTS                                        ESGEPS.40
C     CHECK PLANE STRESS OR STRAIN                                         ESGEPS.41
C     SOIL STRESS-STRAIN RELATIONSHIP                                      ESGEPS.42
      IFINUMATS .EQ. 0) GO TO 407                                          ESGEPS.43
      IF(NPLAN .EQ. 1) GO TO 406                                           ESGEPS.44
C                                                                          ESGEPS.45
C     PLANE STRAIN                                                         ESGEPS.46
      DO 309 I=1,NUMATS                                                    ESGEPS.47
      G=PARASOI1,I)                                                        ESGEPS.48
      ANU=PARASOI3,I)                                                      ESGEPS.49
      B1=2.0*I1.0-ANU)                                                     ESGEPS.50
      B2=1.0-2.0*ANU                                                       ESGEPS.51
      01I1,I)=G*B1/B2                                                      ESGEPS.52
      01(2,I)=G*2.0*ANU/B2                                                 ESGEPS.53
      01I3,II=G                                                            ESGEPS.54
  309 CONTINUE                                                             ESGEPS.55
      GO TO 407                                                            ESGEPS.56
  406 CONTINUE                                                             ESGEPS.57
C                                                                          ESGEPS,58
C     PLANE STRESS                                                         ESGEPS.59
      IFINUMATS .EQ. 0) GO TO 407                                          ESGEPS.60
      DO 310 I=1,NUMATS                                                    ESGEPS.61
      G=PARASOI1,I)                                                        ESGEPS.62
      ANU=PARASOI3,I)                                                      ESGEPS.63
      B1=1.0-ANU                                                           ESGEPS.64
      01I1,I)=G*2.0/B1                                                     ESGEPS.65
      01I2,I)=G*2.0*ANU/B1                                                 ESGEPS.66
      01I3,I)=G                                                            ESGEPS.67
  310 CONTINUE                                                             ESGEPS.68
  407 CONTINUE                                                             ESGEPS.69
C                                                                          ESGEPS.70
C     CONCRETE END FORCES-DEFORMATION RELATIONSHIP                         ESGEPS.71
      IFINUMATC .EQ. 0) GO TO 409                                          ESGEPS.72
C     CALCULATE BEAN AND COLUMN LENGTH ACCORDING TO GEOMETRIC NO.          ESGEPS.73
      DO 317 I=1,NUMGE                                                     ESGEPS.74
      BCLIII=0.0                                                           ESGEPS.75
  317 CONTINUE                                                             ESGEPS.76
      DO 318 N=1,NUMEL                                                     ESGEPS.77
      NG=IBCI1,NI                                                          ESGEPS.78
      IFING .EQ. 0) GO TO 318                                              ESGEPS.79
      DO 319 I=1,2                                                         ESGEPS.80
      NODE=IXII,N)                                                         ESGEPS.81
      XXII)=XINODEI                                                        ESGEPS.82
      YYII)=YINODE)                                                        ESGEPS.83
  319 CONTINUE                                                             ESGEPS.84
      HL=XXI2)-XXI1)                                                       ESGEPS.85
      VL=YYI2)-YY(1)                                                       ESGEPS.86
      BL=SQRTIHL**2+VL**2I                                                 ESGEPS.87
      BCL(NGI=BL*12.0                                                      ESGEPS.88
  318 CONTINUE                                                             ESGEPS.89
      DO 311 I=1,NUMATC                                                    ESGEPS.90
      E=PARACOI1,I)                                                        ESGEPS.91
      ANU=PARACOI3,I)                                                      ESGEPS.92
      G=E/I2.0*I1.0+ANU))                                                  ESGEPS.93
      DO 312 J=1,NUMGE                                                     ESGEPS.94
      AA=COPROPI1,J)                                                       ESGEPS.95
      AV=COPROPI2,J)                                                       ESGEPS.96
      AI=COPROPI3,JI                                                       ESGEPS.97
      BE=12.0*E*AI                                                         ESGEPS.98
      BET=BE/IAV*GI                                                        ESGEPS.99
      BETA=BET/BCLIJ)**2.0                                                 ESGEPS.100
      D2I1,I,J)=E*AA/BCLIJ)                                                ESGEPS.101
      02I2,I,J)=BE/(BCLIJI**3.0*I1.0+BETAI)                                ESGEPS.102
      02I3,I,J)=I4.0+BETA)/IBCLIJ)*I1.0+BETA))                             ESGEPS.103
      02(3,I,J)=02I3,I,J)*E*AI                                             ESGEPS.104
      02I4,I,J)=BE/I2.0*BCLIJI**2.0*(1.0+BETA))                            ESGEPS.105
      02I5,I,J)=I2.0-BETA)*E*AI/(BCLIJ)*I1.0+BETA))                        ESGEPS.106
  312 CONTINUE                                                             ESGEPS.107
  311 CONTINUE                                                             ESGEPS.108
C                                                                          ESGEPS.109
C     FRICTIONAL ELEMENT NODAL FORCE-DISPLACEMENT RELATION IN LOCAL COORE  ESGEPS.110
  409 CONTINUE                                                             ESGEPS.111
      IF(NUMATF .EQ. 0) GO TO 410                                          ESGEPS.112
      DO 313 I=1,NUMATF                                                    ESGEPS.113
      AKS=PARAFRI1,II                                                      ESGEPS.114
      AKN=PARAFRI2,I)                                                      ESGEPS.115
      03I1,I)=AKS/3.0                                                      ESGEPS.116
      03I2,I)=AKN/3.0                                                      ESGEPS.117
      03I3,I)=AKS/6.0                                                      ESGEPS.118
      03I4,II=AKN/6.0                                                      ESGEPS.119
  313 CONTINUE                                                             ESGEPS.120
  410 CONTINUE                                                             ESGEPS.121
C                                                                          ESGEPS.122
C     EXPANSION JOINT NODAL FORCE-DISPLACEMENT RELATIONSHIP IN LOCAL COOE  ESGEPS.123
      IFINUMATE .EQ. 0) GO TO 411                                          ESGEPS.124
      AKS=3000000.0                                                        ESGEPS.125
      AKN=3000000.0                                                        ESGEPS.126
      DO 314 I=1,NUMATE                                                    ESGEPS.127
      04I1,II=AKS/3.0                                                      ESGEPS.128
      04I2,I)=AKN/3.0                                                      ESGEPS.129
      D4I3,I)=AKS/6.0                                                      ESGEPS.130
      04I4,II=AKN/6.0                                                      ESGEPS.131
  314 CONTINUE                                                             ESGEPS.132
  411 CONTINUE                                                             ESGEPS.133
C                                                                          ESGEPS.134
C     BOUNDARY ELEMENT FORCE-DISPLACEMENT RELATIONSHIP                     ESGEPS.135
      IFINUMATB .EQ. 0) GO TO 408                                          ESGEPS.136
      DO 315 I=1,NUMATB                                                    ESGEPS.137
      E=PARABO(1,I)                                                        ESGEPS.138
      05I1,II=E                                                            ESGEPS,139
  315 CONTINUE                                                             ESGEPS.140
C                                                                          ESGEPS.141
C     FORM STRESS-STRAIN MATRIX--CI5,N),ELEMENT BY ELEMENT                 ESGEPS.142
  408 CONTINUE                                                             ESGEPS.143
      DO 316 N=1,NUMEL                                                     ESGEPS.144
C                                                                          ESGEPS.145
C     DETERMINE WHICH ELEMENT TYPE                                         ESGEPS.146
      NTYPE=IXI5,NI                                                        ESGEPS.147
      GO TO I401,402,403,404,405),NTYPE                                    ESGEPS.148
  401 CONTINUE                                                             ESGEPS.149
C                                                                          ESGEPS.150
C     DETERMINE MATERIAL NUMBER                                            ESGEPS.151
      MAT=IXI6,N)                                                          ESGEPS.152
      C(1,NI=01I1,MAT)                                                     ESGEPS.153
      CI2,NI=01I2,MAT)                                                     ESGEPS.154
      CI3,N)=01I3,MAT)                                                     ESGEPS.155
      GO TO 316                                                            ESGEPS.156
C                                                                          ESGEPS.157
C     CONCRETE ELEMENT                                                     ESGEPS.158
C     DETERMINE MATERIAL NO. AND GEOMETRIC NO.                             ESGEPS.159
  402 CONTINUE                                                             ESGEPS.160
      MAT=IXI6,NI                                                          ESGEPS.161
      NG=IBCI1,NI                                                          ESGEPS.162
      CI1,NI=02I1,MAT,NGI                                                  ESGEPS.163
      C(2,NI=02I2,MAT,NG)                                                  ESGEPS.164
      C(3,N)=02I3,MAT,NGI                                                  ESGEPS.165
      CI4,NI=02I4,MAT,NG)                                                  ESGEPS.166
      CI5,NI=02(5,MAT,NG)                                                  ESGEPS.167
      GO TO 316                                                            ESGEPS.168
C                                                                          ESGEPS.169
C     FRICTIONAL ELEMENT                                                   ESGEPS.170
  403 CONTINUE                                                             ESGEPS.171
      MAT=IXI6,N)                                                          ESGEPS.172
      CII,NI=03I1,MATI                                                     ESGEPS.173
      CI2,N)=03I2,MAT)                                                     ESGEPS.174
      CI3,NI=03I3,MAT)                                                     ESGEPS.175
      C(4,N)=03I4,MAT)                                                     ESGEPS.176
      GO TO 316                                                            ESGEPS.177
C     EXPANSION JOINT ELEMANT                                              ESGEPS.178
  404 CONTINUE                                                             ESGEPS.179
      MAT=IXI6,N)                                                          ESGEPS.180
      CI1,N)=D4I1,MAT)                                                     ESGEPS.181
      C(2,N)=04I2,MAT)                                                     ESGEPS.182
      CI3,N)=04I3,MAT)                                                     ESGEPS.183
      CI4,N)=04(4,MAT)                                                     ESGEPS.184
      GO TO 316                                                            ESGEPS.185
C     BOUNDARY SPRING                                                      ESGEPS.186
C                                                                          ESGEPS.187
  405 CONTINUE                                                             ESGEPS.188
      MAT=IXI6,N)                                                          ESGEPS.189
      C(1,N)=05I1,MAT)                                                     ESGEPS.190
  316 CONTINUE                                                             ESGEPS.191
      RETURN                                                               ESGEPS.192
      END                                                                  ESGEPS.193
```

```
      SUBROUTINE ETSTIF(ID,X,Y,PARACO,COPROP,IX,)BC,SLV,C,AE,NIND,NUMEL,ETSTIF.2
     1                  NEQ,MBAND)                                      ETSTIF.3
C                                                                       ETSTIF.4
C     ****************************************************************ETSTIF.5
C     FORM ELASTIC TOTAL STIFFNESS MATRIX AE(NEQ,MBAND)                 ETSTIF.6
C     ****************************************************************ETSTIF.T
C                                                                       ETSTIF.8
      DIMENSION ID(3,1),X(1),Y(1),PARACO(5,1),COPROP(3,1),IX(6,1),      ETSTIF.9
     1          IBC(4,1),SLV(1),C(5,1),AE(NEQ,1),XX(4),YY(4),NIND(1),   ETSTIF.10
     2          SY(6,6)                                                 ETSTIF.11
      COMMON/EM/LN(8),ASA(8,8)                                          ETSTIF.12
      COMMON/NUML/NREAD                                                 ETSTIF.13
C                                                                       ETSTIF.14
C     FORM ELEMENT STIFF MATRIX,ONE BY ONE,AND STORE ON TAPE 1          ETSTIF.15
C                                                                       ETSTIF.16
C     INITILIZATION                                                     ETSTIF.17
      NREAD=0                                                           ETSTIF.18
      DO 351 I=1,NEQ                                                    ETSTIF.19
      DO 351 J=1,MBAND                                                  ETSTIF.20
  351 AE(I,J)=0.0                                                       ETSTIF.21
      DO 352 I=1,6                                                      ETSTIF.22
      DO 352 J=1,6                                                      ETSTIF.23
  352 SY(I,J)=0.0                                                       ETSTIF.24
      DO 353 I=1,NUMEL                                                  ETSTIF.25
  353 NIND(I)=0                                                         ETSTIF.26
      DO 301 N=1,NUMEL                                                  ETSTIF.27
      MTYPE=IX(5,N)                                                     ETSTIF.28
C                                                                       ETSTIF.29
C     DETERMINE THE ELEMENT TYPE                                        ETSTIF.30
      GO TO (401,402,403,403,405),MTYPE                                 ETSTIF.31
C                                                                       ETSTIF.32
C     TYPE 1,SOIL ELEMENT                                               ETSTIF.33
  401 CONTINUE                                                          ETSTIF.34
C                                                                       ETSTIF.35
C     LOCATION OF MASS                                                  ETSTIF.36
      CALL LAM(ID,X,Y,IX,XX,YY,N)                                       ETSTIF.3T
      CALL QUADS(XX,YY,C(1,N),SY,NIND(N))                               ETSTIF.38
C                                                                       ETSTIF.39
C     STORE ON TOTAL STIFFNESS MATRIX AE                                ETSTIF.40
      CALL STORE(AE,NEQ)                                                ETSTIF.41
      GO TO 406                                                         ETSTIF.42
C                                                                       ETSTIF.43
C     TYPE 2,BEAM,COLUMN ELEMENT                                        ETSTIF.44
  402 CONTINUE                                                          ETSTIF.45
C                                                                       ETSTIF.46
C     LOCATION OF MASS                                                  ETSTIF.47
      CALL LAM(ID,X,Y,IX,XX,YY,N)                                       ETSTIF.48
      CALL CONCTS(XX,YY,PARACO,COPROP,IX(1,N),IBC(1,N),C(1,N),SLV,SY,   ETSTIF.49
     1            NIND(N))                                              ETSTIF.50
C     STORE ON TOTAL STIFFNESS MATRIX AE                                ETSTIF.51
      CALL STORE(AE,NEQ)                                                ETSTIF.52
      GO TO 406                                                         ETSTIF.53
C                                                                       ETSTIF.54
C     TYPE 3,FRICTIONAL ELEMENT STIFFNESS                               ETSTIF.55
C     TYPE 4,EXPANSION JOINT                                            ETSTIF.56
  403 CONTINUE                                                          ETSTIF.5T
C                                                                       ETSTIF.58
C     LOCATION OF MASS                                                  ETSTIF.59
      CALL LAM(ID,X,Y,IX,XX,YY,N)                                       ETSTIF.60
C                                                                       ETSTIF.61
      CALL FRICTS(XX,YY,C(1,N))                                         ETSTIF.62
C     STORE ON TOTAL STIFFNESS MATRIX AE                                ETSTIF.63
      CALL STORE(AE,NEQ)                                                ETSTIF.64
      GO TO 406                                                         ETSTIF.65
C                                                                       ETSTIF.66
C     TYPE 5,BOUNDARY ELEMENT                                           ETSTIF.6T
  405 CONTINUE                                                          ETSTIF.68
      DO 314 I=1,2                                                      ETSTIF.69
      NODE=IX(I,N)                                                      ETSTIF.70
      II=ID(1,NODE)                                                     ETSTIF.T1
      LN(I)=II                                                          ETSTIF.T2
  314 CONTINUE                                                          ETSTIF.73
      CALL BOUNDS(C(1,N))                                               ETSTIF.74
C     STORE ON TOTAL STIFFNESS MATRIX AE                                ETSTIF.T5
      DO 315 I=1,2                                                      ETSTIF.76
      II=LN(I)                                                          ETSTIF.TT
      IF(II .EQ. 0) GO TO 315                                           ETSTIF.T8
      DO 316 J=1,2                                                      ETSTIF.79
      JJ=LN(J)-II+1                                                     ETSTIF.80
      IF(JJ .LT. 1) GO TO 316                                           ETSTIF.81
      AE(II,JJ)=AE(II,JJ)+ASA(I,J)                                      ETSTIF.82
  316 CONTINUE                                                          ETSTIF.83
  315 CONTINUE                                                          ETSTIF.84
  406 CONTINUE                                                          ETSTIF.85
  301 CONTINUE                                                          ETSTIF.86
C     FORM ELASTIC TOTAL STIFFNESS AE(NEQ,MBAND),AND STORE ON TAPE 3    ETSTIF.8T
      WRITE(3) ((AE(I,J),I=1,NEQ),J=1,MBAND)                            ETSTIF.88
      RETURN                                                            ETSTIF.89
      END                                                               ETSTIF.90
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      SUBROUTINE LAM(ID,X,Y,IX,XX,YY,N)                                 LAM.2
C     ****************************************************************LAM.3
C     CALCULATE LOCATION OF MASS--LM                                    LAM.4
C     ****************************************************************LAM.5
      COMMON/EM/LN(8),ASA(8,8)                                          LAM.6
      DIMENSION ID(3,1),X(1),Y(1),IX(6,1),XX(4),YY(4)                   LAM.T
      I2=IX(2,N)                                                        LAM.8
      I3=IX(3,N)                                                        LAM.9
      IF(I2 .EQ. I3) GO TO 401                                          LAM.10
C                                                                       LAM.11
C     QUADRATERAL ELEMENT--SOIL,FRICTON,EXPANSION JOINT ELEMENT         LAM.12
      DO 301 I=1,4                                                      LAM.13
      NODE=IX(I,N)                                                      LAM.14
      JJ=I+I                                                            LAM.15
      LN(JJ)=ID(2,NODE)                                                 LAM.16
      LN(JJ-1)=ID(1,NODE)                                               LAM.17
      XX(I)=X(NODE)                                                     LAM.18
      YY(I)=Y(NODE)                                                     LAM.19
  301 CONTINUE                                                          LAM.20
      GO TO 402                                                         LAM.21
  401 CONTINUE                                                          LAM.22
C     ONE DIMENSIONAL ELEMENT --BEAM,COLUMN                             LAM.23
C                                                                       LAM.24
      LN(T)=0                                                           LAM.25
      LM(8)=0                                                           LAM.26
      DO 302 I=1,2                                                      LAM.2T
      NODE=IX(I,N)                                                      LAM.28
      JJ=3*I                                                            LAM.29
      LN(JJ)=ID(3,NODE)'                                                LAM.30
      LN(JJ-1)=ID(2,NODE)                                               LAM.31
      LN(JJ-2)=ID(1,NODE)                                               LAM.32
      XX(I)=X(NODE)                                                     LAM.33
      YY(I)=Y(NODE)                                                     LAM.34
  302 CONTINUE                                                          LAM.35
  402 CONTINUE                                                          LAM.36
      RETURN                                                            LAM.37
      END                                                               LAM.38
```

```
      SUBROUTINE STORE(AE,NEQ)                                          STORE.2
C     ************************************************************      STORE.3
C     STORE ELEMENT STIFFNESS INTO TOTAL STIFFNESS MATRIX AE(NEQ,MBAND) STORE.4
C     ************************************************************      STORE.5
      COMMON/EM/LM(8),ASA(8,8)                                          STORE.6
      DIMENSION AE(NEQ,1)                                               STORE.7
      DO 301 I=1,8                                                      STORE.8
      II=LM(I)                                                          STORE.9
      IF(II .EQ. 0) GO TO 301                                           STORE.10
      DO 302 J=1,8                                                      STORE.11
      JJ=LM(J)-II+1                                                     STORE.12
      IF(JJ .LT. 1) GO TO 302                                           STORE.13
      AE(II,JJ)=AE(II,JJ)+ASA(I,J)                                      STORE.14
  302 CONTINUE                                                          STORE.15
  301 CONTINUE                                                          STORE.16
      RETURN                                                            STORE.17
      END                                                               STORE.18
```

```
      SUBROUTINE QUADS(XX,YY,E,SY,IND)                                  QUADS.2
C                                                                       QUADS.3
C     ************************************************************      QUADS.4
C     FORM SOIL ELEMENT STIFFNESS MATRIX,AND STORE ON TAPE 1            QUADS.5
C     ************************************************************      QUADS.6
C                                                                       QUADS.7
      DIMENSION XX(4),YY(4),E(5),SS(4),TT(4),H(4),HS(4),HT(4),          QUADS.8
     1          HX(4),HY(4)                                             QUADS.9
      DIMENSION B(3,8),S(6,6),SA(3,8),SY(6,6)                           QUADS.10
      COMMON/EM/LM(8),ASA(8,8)                                          QUADS.11
      COMMON/NONL/NREAD                                                 QUADS.12
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NINTCV,TMICRQUADS.13
     1,NPLAN                                                            QUADS.14
      COMMON/ELASTC/SE(8,8)                                             QUADS.15
        COMMON/TIME/JUMP,T,DT,NPRTM,NTAPE,KPRINT                        QUADS.16
      DATA SS/-1.0,1.0,1.0,-1.0/, TT/-1.0,-1.0,1.0,1.0/                 QUADS.17
C                                                                       QUADS.18
C     INITIALIZATION                                                    QUADS.19
      DO 301 I=1,8                                                      QUADS.20
      DO 302 J=1,8                                                      QUADS.21
  302 ASA(I,J)=0.0                                                      QUADS,22
  301 CONTINUE                                                          QUADS.23
      DO 303 I=1,3                                                      QUADS.24
      DO 304 J=1,8                                                      QUADS.25
  304 B(I,J)=0.0                                                        QUADS.26
  303 CONTINUE                                                          QUADS.27
C                                                                       QUADS.28
C                                                                       QUADS.29
      DO 305 I=1,4                                                      QUADS.30
      SC=SS(I)*0.57735026918963                                         QUADS.31
      TC=TT(I)*0.57735026918963                                         QUADS.32
      SM=1.0-SC                                                         QUADS.33
      SP=1.0+SC                                                         QUADS.34
      TM=1.0-TC                                                         QUADS.35
      TP=1.0+TC                                                         QUADS.36
C                                                                       QUADS.37
C     FORM INTERPOLATION FCTNS                                          QUADS.38
      H(1)=SM*TM/4.0                                                    QUADS.39
      H(2)=SP*TM/4.0                                                    QUADS.40
      H(3)=SP*TP/4.0                                                    QUADS.41
      H(4)=SM*TP/4.0                                                    QUADS.42
C                                                                       QUADS.43
C     DERIVATIVE OF H W.R.T. S,D(H(I))/DS=HS(I)                         QUADS.44
      HS(1)=-TM/4.0                                                     QUADS.45
      HS(2)=-HS(1)                                                      QUADS.46
      HS(3)=TP/4.0                                                      QUADS.47
      HS(4)=-HS(3)                                                      QUADS.48
C                                                                       QUADS.49
C     DERIVATIVE W.R.T. T,D(H(I))/DT=HT(I)                              QUADS.50
      HT(1)=-SM/4.0                                                     QUADS.51
      HT(2)=-SP/4.0                                                     QUADS.52
      HT(3)=-HT(2)                                                      QUADS.53
      HT(4)=-HT(1)                                                      QUADS.54
C                                                                       QUADS.55
C     FORM PARTIAL DERIVATIVE OF X,Y W.R.T. S,T                         QUADS.56
C     PYT=DY/DT,PYS=DY/DS,PXS=DX/DS,PXT=DX/DT                           QUADS.57
C     XJ=JACOBIAN=(DX/DS)*(DY/DT)-(DX/DT)*(DY/DS)                       QUADS.58
      PYT=HT(1)*YY(1)+HT(2)*YY(2)+HT(3)*YY(3)+HT(4)*YY(4)               QUADS.59
      PYS=HS(1)*YY(1)+HS(2)*YY(2)+HS(3)*YY(3)+HS(4)*YY(4)               QUADS.60
      PXT=HT(1)*XX(1)+HT(2)*XX(2)+HT(3)*XX(3)+HT(4)*XX(4)               QUADS.61
      PXS=HS(1)*XX(1)+HS(2)*XX(2)+HS(3)*XX(3)+HS(4)*XX(4)               QUADS.62
      XJ=PXS*PYT-PXT*PYS                                                QUADS.63
C                                                                       QUADS.64
C     FORM D(H(I))/DX=HX(I) AND D(H(I))/DY)=HY(I) IN STRAIN-DISPLACEMENT QUADS.65
      PSX=PYT/XJ                                                        QUADS.66
      PTX=-PYS/XJ                                                       QUADS.67
      PSY=-PXT/XJ                                                       QUADS.68
      PTY=PXS/XJ                                                        QUADS.69
      DO 306 I=1,4                                                      QUADS.70
      HX(I)=PSX*HS(I)+PTX*HT(I)                                         QUADS.71
      HY(I)=PSY*HS(I)+PTY*HT(I)                                         QUADS.72
      HX(I)=HX(I)/12.0                                                  QUADS.73
      HY(I)=HY(I)/12.0                                                  QUADS.74
  306 CONTINUE                                                          QUADS.75
C                                                                       QUADS.76
C     FORM STRAIN-DISPLACEMENT MATRIX B(3,8)                            QUADS.77
      B(1,1)=HX(1)                                                      QUADS.78
      B(1,3)=HX(2)                                                      QUADS.79
      B(1,5)=HX(3)                                                      QUADS.80
      B(1,7)=HX(4)                                                      QUADS.81
      B(2,2)=HY(1)                                                      QUADS.82
      B(2,4)=HY(2)                                                      QUADS.83
      B(2,6)=HY(3)                                                      QUADS.84
      B(2,8)=HY(4)                                                      QUADS.85
C                                                                       QUADS.86
      B(3,1)=B(2,2)                                                     QUADS.87
      B(3,2)=B(1,1)                                                     QUADS.88
      B(3,3)=B(2,4)                                                     QUADS.89
      B(3,4)=B(1,3)                                                     QUADS.90
      B(3,5)=B(2,6)                                                     QUADS.91
      B(3,6)=B(1,5)                                                     QUADS.92
      B(3,7)=B(2,8)                                                     QUADS.93
      B(3,8)=B(1,7)                                                     QUADS.94
C                                                                       QUADS.95
      IF(IND .EQ. 1) GO TO 401                                          QUADS.96
C     ELASTIC CASE                                                      QUADS.97
C     STRESS-STRAIN MATRIX S(3,3)                                       QUADS.98
      S(1,1)=E(1)                                                       QUADS.99
      S(1,2)=E(2)                                                       QUADS.100
      S(1,3)=0.0                                                        QUADS.101
      S(2,1)=E(2)                                                       QUADS.102
      S(2,2)=E(1)                                                       QUADS.103
      S(2,3)=0.0                                                        QUADS.104
      S(3,1)=0.0                                                        QUADS.105
      S(3,2)=0.0                                                        QUADS.106
      S(3,3)=E(3)                                                       QUADS.107
  403 CONTINUE                                                          QUADS.108
      GO TO 402                                                         QUADS.109
  401 CONTINUE                                                          QUADS.110
C                                                                       QUADS.111
C     PLASTIC STRESS-STRAIN MATRIX S(3,3)                               QUADS.112
      DO 309 I=1,3                                                      QUADS.113
      DO 309 J=1,3                                                      QUADS.114
  309 S(I,J)=SY(I,J)                                                    QUADS.115
  402 CONTINUE                                                          QUADS.116
C                                                                       QUADS.117
C     FORM ELEMENT STIFFNESS MATRIX ASA(I,J)                            QUADS.118
      FAC=THICK*XJ*1728.0                                               QUADS.119
      DO 307 J=1,8                                                      QUADS.120
      D1=FAC*(S(1,1)*B(1,J)+S(1,2)*B(2,J)+S(1,3)*B(3,J))                QUADS.121
      D2=FAC*(S(2,1)*B(1,J)+S(2,2)*B(2,J)+S(2,3)*B(3,J))                QUADS.122
      D3=FAC*(S(3,1)*B(1,J)+S(3,2)*B(2,J)+S(3,3)*B(3,J))                QUADS.123
      DO 308 I=J,8                                                      QUADS.124
      ASA(I,J)=ASA(I,J)+B(1,I)*D1+B(2,I)*D2+B(3,I)*D3                   QUADS.125
      ASA(J,I)=ASA(I,J)                                                 QUADS.126
  308 CONTINUE                                                          QUADS.127
  307 CONTINUE                                                          QUADS.128
  305 CONTINUE                                                          QUADS.129
      IF(NREAD .EQ. 1) GO TO 410                                        QUADS.130
C                                                                       QUADS.131
C     STORE ELEMENT STIFFNESS INFORMATION ON TAPE 1                     QUADS.132
      NO=8                                                              QUADS.133
      NS=3                                                              QUADS.134
```

```
      WRITE(1) NO,NS,(LM(I),I=1,NO),(((S(I,J),I=1,NS),J=1,NS),          QUADS.135
     1         ')(B(I,J),)=1,NS),J=1,NO)                               QUADS.136
       GO TO 411                                                       QUADS.137
  410 CONTINUE                                                        QUADS.138
C     WRITE NON-LINEAR INFORMATION ON TAPE 41                         QUADS.139
      DO 310 (=1,3                                                    QUADS.140
      DO 310 J=I,3                                                    QUADS.141
      S)),J)=SE)',J)-S(),J)                                           QUADS.142
  310 CONTINUE                                                        QUADS.143
      WR)TE)41)NO,NS,(LM(I),I=1,NO),(((S(I,J),I=1,NS),J=1,NS),        QUADS.144
     1         ()B(I,J),I=1,NS),J=1,NO)                               QUADS.145
  411 CONTINUE                                                        QUADS.146
      RETURN                                                          QUADS.14T
      END                                                             QUADS.148
```

```
      SUBROUTINE CONCTS(XX,YY,PARACO,COPRDP,IX,IBC,C,SLV,SY,NINO)     CONCTS.2
C                                                                     CONCTS.3
C     ****************************************************************CONCTS,4
C     FORM ELEMENT STIFFNESS OF BEAM,COLUMN IN GLOBAL'COORD --ASA     CONGTS,5
C     ****************************************************************CONCTS.6
C                                                                     CONCTS.7
      DIMENSION XX(4),YY(4),PARACO(5,1),CDPROP(3,1),IXI6),C(5),IBC(4),CONCTS.8
     1          SLV)1),SY(6,6)                                        CONCTS.9
      DIMENSION T)3,3),JK(2),S(8,8),R(6),CC(6),SF(6),SA(8,8)          CONCTS.10
      COMMON/EM/LM)8),ASA(8,8)                                        CONCTS.11
      DIMENSION TI(3,3),SFL(6)                                        CONCTS.12
      COMMON/MONL/NREAD                                               CONCTS.13
      DIMENSION SL)6,6)                                               CONCTS.14
      COMMON/ELASTC/SAL(8,8)                                          CONCTS.15
      DIMENSION SFGU(6),RF(6)                                         CONCTS.16
      COMMON/TIME/JUMP,B,DT,MPRTH,MTAPE,KPRINT                        CONCTS.17
C                                                                     CONCTS,18
C     FORM GLOBAL TO LOCAL COORDS TRANFORMATION MATRIX--T(2,2)        CONCTS.19
      DX=XX(2)-XX(1)                                                  CONCTS.20
      DY=YY)2)-YY(1)                                                  CONCTS.21
      DL=SQRT(DX**2+DY**2)                                            CONCTS.22
      T(1,1)=DX/DL                                                    CONCTS,23
      T(1,2)=DY/DL                                                    CONCTS.24
      T)1,3)=0.D                                                      CONCTS,25
      T)2,1)=-T)1,2)                                                  CONCTS.26
      T(2,2)=T(1,1)                                                   CONCTS.2T
      T)2,3)=0.D                                                      CONCTS.28
      T(3,1)=0.0                                                      CONCTS.29
      T(3,2)=D.D                                                      CONCTS,30
      T(3,3)=1.0                                                      CONCTS.31
C                                                                     CONCTS.32
C     BEAM END RELEASE CODE                                           CONCTS.33
      JK(I)=IBC)2)                                                    CONCTS.34
      JK)2)=IBC(3)                                                    CONCTS.35
C                                                                     CONCTS.36
C     FORM ELEMENT STIFFNESS MATRIX IN LOCAL COORD--S(8,8)            CONCTS.37
      OO 3O2 I=1,8                                                    CONCTS.38
      DO 3O2 J=1,8                                                    CONCTS.39
  302 S(1,J)=0.0                                                      CONCTS.40
      IF)NINO .NE. D) GO TO 401                                       CONCTS.41
      S)1,1)=C(1)                                                     CONCTS.42
      S(2,2)=C)2)                                                     CONCTS.43
      S(3,3)=C(3)                                                     CONCTS.44
      S(3,2)=C)4)                                                     CONCTS.45
      S(4,1)=-C(1)                                                    CONCTS.46
      S)4,4)=S(1,1)                                                   CONCTS.4T
      S)S,2)=-S)2,2)                                                  CONCTS.48
      S(5,3)=-S(3,2)                                                  CONCTS.49
      S(5,S)=S)2,2)                                                   CONCTS.SO
      S)6,2)=S(3,2)                                                   CONCTS.51
      S)6,3)=C(S)                                                     CONCTS.52
      S)6,5)=-S(6,2)                                                  CONCTS.53
      S)6,6)=S(3,3)                                                   CONCTS.S4
      DO 303 )=1,6                                                    CONCTS.SS
      OD 304 J=),6                                                    CONCTS.S6
  304 S)I,J)=S(J,I)                                                   CONCTS.5T
  303 CONTINUE                                                        CONCTS.58
      OO 322 )=1,6                                                    CONCTS.59
      DO 322 J=1,6                                                    CONCTS.6O
      SL(I,J)=S)I,J)                                                  CONCTS.61
  322 CONTINUE                                                        CONCTS.62
      GO TO 402                                                       CONCTS.63
  401 CONTINUE                                                        CONCTS.64
      DO 353 I=1,6                                                    CONCTS.65
      OO 353 J=1,6                                                    CONCTS.66
  353 S(I,J)=SY(I,J)                                                  CONCTS.6T
  402 CONTINUE                                                        CONCTS.68
      IF(NREAO .EO. 1) GO TO 411                                      CONCTS.69
C                                                                     CONCTS.TO
C     FIXED END FORCES--SF(6)                                         CONCTS.T1
C     FORM FIXEO END FORCES                                           CONCTS.T2
      MATYPE=IX(6)                                                    CONCTS.T3
      NG=IBC(1)                                                       CONCTS.T4
      AXA=COPROP(1,NG)                                                CONCTS.TS
      WT=AXA*PARACO(5,MATYPE)/144.0                                   CONCTS.76
      AMASS=AXA*PARACO)4,MATYPE)/144.O                                CONCTS.TT
      CALL F8ECOL)XX,YY,AMASS,WT,FEN)                                 CONCTS.T8
      DO 352 I=1,6                                                    CONCTS.T9
      SF())=0.O                                                       CONCTS.8O
  352 CONTINUE                                                        CONCTS.81
C     GLOBAL FORCES                                                   CONCTS.82
      SF(1)=0.O                                                       CONCTS.83
      SF(2)=WT                                                        CONCTS.84
      SF(3)=FEM                                                       CONCTS.85
      SF(4)=0.O                                                       CONCTS.86
      SF(5)=WT                                                        CONCTS.8T
      SF(6)=-FEM                                                      CONCTS.88
      DO 334 I=1,6                                                    CONCTS.89
      SFGU(I)=SF(I)                                                   CONCTS.9O
  334 CONTINUE                                                        CONCTS.91
C     TRANSFORM TO LOCAL COORDINATES                                  CONCTS.92
      TI(1,1)=T(1,1)                                                  CONCTS.93
      TI(1,2)=T(1,2)                                                  CONCTS.94
      TI(1,3)=O.O                                                     CONCTS.95
      TI(2,1)=T(2,1)                                                  CONCTS.96
      TI(2,2)=T(2,2)                                                  CONCTS.97
      T1(2,3)=0.O                                                     CONCTS.98
      TI(3,1)=O.O                                                     CONCTS.99
      TI(3,2)=0.O                                                     CONCTS.1OO
      TI(3,3)=1.O                                                     CONCTS.101
      SFL(1)=TI(1,1)*SF(1)+TI(1,2)*SF(2)                              CONCTS.102
      SFL(2)=TI(2,1)*SF(1)+TI(2,2)*SF(2)                              CONCTS.1O3
      SFL(3)=SF(3)                                                    CONCTS,104
      SFL(4)=TI(1,1)*SF(4)+TI(1,2)*SF)5)                              CONCTS.1O5
      SFL(5)=TI(2,1)*SF(4)+TI(2,2)*SF(5)                              CONCTS.1O6
      SFL(6)=SF(6)                                                    CONCTS.1OT
      DO 321 I=1,6                                                    CONCTS.1O8
      SF(I)=SFL(I)                                                    CONCTS.1O9
  321 CONTINUE                                                        CONCTS.11O
  411 CONTINUE                                                        CONCTS.111
C                                                                     CONCTS.112
C     MODIFY ELEMENT STIFFNESS AND FIXEO END FORCES FOR KNOWN ZERO MEMBECONCTS.113
      IF((JK(1)+JK(2)) .EO. O) GO TO 413                              CONCTS.114
      DO 306 K=1,2                                                    CONCTS.115
      KK=JK(K)                                                        CONCTS.116
      KD=100                                                          CONCTS.11T
      I1=3*)K-1)+1                                                    CONCTS.118
      I2=I1+2                                                         CONCTS.119
      DO 306 I=I1,I2                                                  CONCTS.120
      IF(KK .LT. KO) GO TO 306                                        CONCTS.121
      SII=S(I,I)                                                      CONCTS.122
      DO 3DT N=1,6                                                    CONCTS.123
 3DT R(N)=S)I,N)                                                      CONCTS.124
      DO 3D8 M=1,6                                                    CONCTS.125
      CC(M)=S(M,I)/SII                                                CONCTS.126
      DD 3D8 N=1,6                                                    CONCTS.127
  308 S(M,N)=S)M,N)-CC)M)*R)N)                                        CONCTS.128
      IF(NREAO .EO. I) GO TO 412                                      CONCTS.129
      SF1=SF)I)                                                       CONCTS.130
      DO 3D9 M=1,6                                                    CONCTS.131
  309 SF)M)=SF)M)-CC(M)*SF)                                           CONCTS.132
  412 CONTINUE                                                        CONCTS.133
      KK=KK-KD                                                        CONCTS.134
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  306 KO=KD/ID                                                          CONCTS.135
      IF(NREAD .ED. 1) GO TO 413                                        CONCTS.136
C                                                                       CONCTS.137
C     FIXED END FORCE RF(6) IN GLOBAL COORDINATE                        CONCTS.138
      DO 331 LA=1,4,3                                                   CONCTS.139
      LB=LA-1                                                           CONCTS.140
      OD 331 IL=I,3                                                     CONCTS.141
      I=IL+LB                                                           CONCTS.142
      XA=D.O                                                            CONCTS.143
      DO 332 K=1,3                                                      CONCTS.144
  332 XA=XA-T(K,IL)*SF(K+LB)                                            CONCTS.145
  331 RF(I)=XA                                                          CONCTS.146
  41' CONTINUE                                                          CONCTS.147
.C                                                                      CONCTS.148
C     OBTAIN SA(6,6) RELATING ELEMENT END FORCES(LOCAL) TO              CONCTS.149
C     JOINT DISPLACEMENT(GLOBAL)                                        CONCTS.150
      DO 311 I=1,64                                                     CONCTS.151
      SA(I)=O.D                                                         CONCTS.152
  311 CONTINUE                                                          CONCTS.153
      DO 312 LA=1,4,3                                                   CONCTS.154
      LB=LA+2                                                           CONCTS.155
      DO 312 MA=1,4,3                                                   CONCTS.156
      MB=MA-1                                                           CONCTS.157
      DO 312 I=LA,LB                                                    CONCTS.158
      DO 312 JM=1,3                                                     CONCTS.159
      J=JM+MB                                                           CONCTS.160
      XA=O.O                                                            CONCTS.161
      DO 313 K=1,3                                                      CONCTS.162
  313 XA=XA+S(I,K+MB)*T(K,JM)                                           CONCTS.163
  312 SA(I,J)=XA                                                        CONCTS.164
C                                                                       CONCTS.165
C     ELEMENT STIFFNESS MATRIX ASA(6,6) IN GLOBAL COORDS                CONCTS.166
      DO 314 I=1,64                                                     CONCTS.167
  314 ASA(I)=D.D                                                        CONCTS.168
      DO 315 LA=1,4,3                                                   CONCTS.169
      LB=LA-1                                                           CONCTS.170
      DO 315 MA=1,4,3                                                   CONCTS.171
      MB=MA+2                                                           CONCTS.172
      DD 315 IL=1,3                                                     CONCTS.173
      I=IL+LB                                                           CONCTS.174
      DO 315 J=MA,MB                                                    CONCTS.175
      XA=D.O                                                            CONCTS.176
      DD 316 K=1,3                                                      CONCTS.177
  316 XA=XA+T(K,IL)*SA(K+LB,J)                                          CONCTS.178
      ASA(I,J)=XA                                                       CONCTS.179
  315 CONTINUE                                                          CONCTS.180
      IF(NREAD .EQ. 1) GO TO 41D                                        CONCTS.181
      NS=6                                                              CONCTS.182
      MD=6                                                              CONCTS.183
      WRITE(1) ND,NS,(LM(I),I=1,MD),((SL(I,J),I=1,NS),J=1,ND),          CONCTS.184
     1         ((SA(I,J),I=1,NS),J=1,ND),                               CONCTS.185
     2         (SF(I),I=1,MD)                                           CONCTS.186
      GO TO 421                                                         CONCTS.187
  410 CONTINUE                                                          CONCTS.188
C     WRITE NON-LINEAR INFORMATION ON TAPE 41                           CONCTS.189
      DO 318 I=1,6                                                      CONCTS.190
      DO 318 J=1,6                                                      CONCTS.191
      SA(I,J)=SAL(I,J)-SA(I,J)                                          CONCTS.192
  318 CONTINUE                                                          CONCTS.193
      WRITE(41)MD,NS,(LM(I),I=1,ND),((SL(I,J),I=1,NS),J=1,ND),          CONCTS.194
     1         ((SA(I,J),I=1,NS),J=1,MD),                               CONCTS.195
     2         (SF(I),I=1,ND)                                           CONCTS.196
  421 CONTINUE                                                          CONCTS.197
      RETURN                                                            CONCTS.198
      END                                                               CONCTS.199
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      SUBROUTIME FRICTS(XX,YY,C)                                        FRICTS.2
C                                                                       FRICTS.3
C     ****************************************************************FRICTS.4
C     FOEM FRICTIONAL ELEMENT STIFFMESS MATRIX AMD STORE ON TAPE 1      FRICTS.5
C     ****************************************************************FRICTS.6
C                                                                       FRICTS.T
      DIMENSION XX(4),YY(4),C(5),S(8,8),SA(8,8),T(2,2)                  FRICTS.8
      COMMDM/ER/LM(8),ASA(8,8)                                          FRICTS.9
      COMMON/MDNL/MREAD                                                 FRICTS.1D
      COMMON/TIME/JUMP,B,DT,MPRTM,MTAPE,KPRINT                          FRICTS.11
      COMMON/ELASTC/SEA(8,8)                                            FRICTS.12
C                                                                       FRICTS.13
C     IMITILIZATION                                                     FRICTS.14
      DO 301 I=1,64                                                     FRICTS.15
      S(I)=D.D                                                          FRICTS.16
  301 COMTINUE                                                          FRICTS.1T
C                                                                       FRICTS.18
C     FORM ELEMENT STIFFMESS IN LOCAL COORDS--S(8,8)                    FRICTS.19
      S(1,1)=C(1)                                                       FRICTS.20
      S(1,3)=C(3)                                                       FRICTS.21
      S(2,2)=C(2)                                                       FRICTS.22
      S(2,4)=C(4)                                                       FRICTS.23
      S(3,3)=S(1,1)                                                     FRICTS.24
      S(4,4)=S(2,2)                                                     FRICTS.25
      S(1,5)=-S(1,3)                                                    FRICTS.26
      S(1,T)=-S(1,1)                                                    FRICTS.2T
      S(2,6)=-S(2,4)                                                    FRICTS.28
      S(2,8)=-S(2,2)                                                    FRICTS.29
      S(3,5)=-S(1,1)                                                    FRICTS.3D
      SI3,7)=-S(1,3)                                                    FRICTS.31
      S(4,6)=-S(2,2)                                                    FRICTS.32
      S(4,8)=-S(2,4)                                                    FRICTS.33
      DO 303 I=1,4                                                      FRICTS.34
      DO 303 J=1,4                                                      FRICTS.35
  303 S(I+4,J+4)=S(I,J)                                                 FRICTS.36
      DO 304 I=2,8                                                      FRICTS.37
      K=I-1                                                             FRICTS.38
      DO 304 J=1,K                                                      FRICTS.39
      S(I,J)=S(J,I)                                                     FRICTS.4D
  304 CONTINUE                                                          FRICTS.41
C                                                                       FRICTS.42
C     FORM TRANSFORMATION MATRIX TI2,2)                                 FRICTS.43
      DX=XX(2)-XX(1)                                                    FRICTS.44
      OY=YY(2)-YY(1)                                                    FRICTS.45
C     CASE OF MORIZONTAL FRICTION ELEMENT                               FRICTS.46
      IF(DX .ME. O.D .OR. DY .ME. O.D) GO TO 421                        FRICTS.4T
      DX=XX(4)-XX(1)                                                    FRICTS.48
      OY=YY(4)-YY(1)                                                    FRICTS.49
  421 CONTINUE                                                          FRICTS.50
      OL=SQRT(DX**2+DY**2)                                              FRICTS.51
C     STIFFNESS FOR TOTAL LENGTH L,K/INCH                               FRICTS.52
      DO 351 I=1,8                                                      FRICTS.53
      DO 351 J=1,8                                                      FRICTS.54
      S(I,J)=S(I,J)*OL*12.O                                             FRICTS.55
  351 CONTINUE                                                          FRICTS.56
C                                                                       FRICTS.57
      T(1,1)=DX/OL                                                      FRICTS.58
      T(1,2)=DY/OL                                                      FRICTS.59
      T(2,2)=T(1,1)                                                     FRICTS.60
      T(2,1)=-T(1,2)                                                    FRICTS.61
C     FORM SA(8,8),RELATING ELEMENT END FORCES(LOCAL) TO                FRICTS.62
C     JOINT DISPLACEMENT(GLOBAL)                                        FRICTS.63
      DO 305 I=1,64                                                     FRICTS.64
  305 SA(I)=D.D                                                         FRICTS.65
      DO 3D6 LA=1,T,2                                                   FRICTS.66
      LB=LA+1                                                           FRICTS.67
      DO 3D6 MA=1,7,2                                                   FRICTS.68
      MB=MA-1                                                           FRICTS.69
      DD 3D6 I=LA,LB                                                    FRICTS.7D
      DO 3D6 JM=1,2                                                     FRICTS.71
      J=JM+MB                                                           FRICTS.72
      XA=D.D                                                            FRICTS.73
      DO 3D7 K=1,2                                                      FRICTS.74
  3D7 XA=XA+S(I,K+MB)*T(K,JM)                                           FRICTS.75
      SA(I,J)=XA                                                        FRICTS.76
  3D6 CDMTIMUE                                                          FRICTS.77
```

```
C                                                                       FRICTS.77
C     ELEMENT STIFFNESS ASA(8,8) IN GLOBAL COORDS                       FRICTS.78
      DO 308 I=1,64                                                     FRICTS.79
  308 ASA(I)=0.0                                                        FRICTS.80
      DO 309 LA=1,7,2                                                   FRICTS.81
      LB=LA-1                                                           FRICTS.82
      DO 309 MA=1,7,2                                                   FRICTS.83
      MB=MA+1                                                           FRICTS.84
      DO 309 IL=1,2                                                     FRICTS.85
      I=IL+LB                                                           FRICTS.86
      DO 309 J=MA,MB                                                    FRICTS.87
      XA=0.0                                                            FRICTS.88
      DO 310 K=1,2                                                      FRICTS.89
  310 XA=XA+T(K,IL)*SA(K+LB,J)                                          FRICTS.90
      ASA(I,J)=XA                                                       FRICTS.91
  309 CONTINUE                                                          FRICTS.92
      IF(NREAD .EQ. 1) GO TO 410                                        FRICTS.93
C                                                                       FRICTS.94
C     WRITE ELEMENT STIFFNESS INFORMATION ON TAPE 1                     FRICTS.95
      NO=8                                                              FRICTS.96
      NS=8                                                              FRICTS.97
      WRITE(1) ND,NS,(LN(I),I=1,ND),((S(I,J),I=I,NS),J=1,ND),           FRICTS.98
     1         ((SA(I,J),I=1,NS),J=1,ND)                                FRICTS.99
      GO TO 411                                                         FRICTS.100
  410 CONTINUE                                                          FRICTS.101
C     WRITE NON-LINEAR INFORMATION ON TAPE 41                           FRICTS.102
      DO 312 I=1,8                                                      FRICTS.103
      DO 312 J=1,8                                                      FRICTS.104
      SA(I,J)=SEA(I,J)-SA(I,J)                                          FRICTS.105
  312 CONTINUE                                                          FRICTS.106
      WRITE(41)ND,NS,(LN(I),I=1,ND),((S(I,J),I=1,NS),J=1,ND),           FRICTS.107
     1         ((SA(I,J),I=1,NS),J=1,ND)                                FRICTS.108
  411 CONTINUE                                                          FRICTS.109
      RETURN                                                            FRICTS.110
      END                                                               FRICTS.111
```

```
      SUBROUTINE STATIC(SLV,AE,U,V,ACC,DU,OV,DA,NEQ,MBAND)              STATIC.2
C                                                                       STATIC.3
C     ******************************************************************STATIC.4
C     SOLUTION OF STATIC CASE--DISPLACEMENT AT NODES                    STATIC.5
C     ******************************************************************STATIC.6
C                                                                       STATIC.7
      DIMENSION SLV(1),U(1),V(1),ACC(1),DU(1),OV(1),DA(1),AE(NEQ,1)     STATIC.8
      COMMON/TIME/JUMP,T,DT,NPRTN,NTAPE,KPRINT                          STATIC.9
C                                                                       STATIC.10
C      INITILIZATION                                                    STATIC.11
      DO 351 I=1,NEQ                                                    STATIC.12
      V(I)=0.0                                                          STATIC.13
      ACC(I)=0.0                                                        STATIC.14
      DU(I)=0.0                                                         STATIC.15
      DV(I)=0.0                                                         STATIC.16
      DA(I)=0.0                                                         STATIC.17
  351 CONTINUE                                                          STATIC.18
      JUMP=0                                                            STATIC.19
      NPRTN=0                                                           STATIC.20
      KPRINT=0                                                          STATIC.21
      T=0.0                                                             STATIC.22
      REWIND 3                                                          STATIC.23
      READ(3) ((AE(I,J),I=1,NEQ),J=1,NBAND)                             STATIC.24
      DO 301 I=1,NEQ                                                    STATIC.25
      IF(AE(I,1) .NE. 0) U(I)=SLV(I)                                    STATIC.26
  301 CONTINUE                                                          STATIC.27
      CALL TRIA(AE,NEQ,NBAND)                                           STATIC.28
      CALL BACKS(AE,U,NEQ,MBAND)                                        STATIC.29
      DO 302 I=1,NEQ                                                    STATIC.30
      DU(I)=U(I)                                                        STATIC.31
  302 CONTINUE                                                          STATIC.32
      RETURN                                                            STATIC.33
      END                                                               STATIC.34
```



```
      SUBROUTINE BOUNDS(C)                                              BOUNDS.2
C                                                                       BOUNDS.3
C     ******************************************************************BOUNDS.4
C     FORM BOUNDARY ELEMENT STIFFNESS MATRIX AND STORE ON TAPE 1        BOUNDS.5
C     ******************************************************************BOUNDS.6
C                                                                       BOUNDS.7
      COMMON/EM/LN(8),ASA(8,8)                                          BOUNDS.8
      DIMENSION C(5),S(8,8),SA(8,8)                                     BOUNDS.9
      COMMON/NONL/NREAD                                                 BOUNDS.10
      COMMON/ELASTC/SE(8,8)                                             BOUNDS.11
      DO 301 I=1,64                                                     BOUNDS.12
      S(I)=0.0                                                          BOUNDS.13
  301 CONTINUE                                                          BOUNDS.14
      S(1,1)=C(1)                                                       BOUNDS.15
      S(1,2)=-S(1,1)                                                    BOUNDS.16
      S(2,1)=S(1,2)                                                     BOUNDS.17
      S(2,2)=S(1,1)                                                     BOUNDS.18
      DO 302 I=1,8                                                      BOUNDS.19
      DO 302 J=1,8                                                      BOUNDS.20
      SA(I,J)=S(I,J)                                                    BOUNDS.21
      ASA(I,J)=S(I,J)                                                   BOUNDS.22
  302 CONTINUE                                                          BOUNDS.23
      IF(NREAD .EQ. 1) GO TO 410                                        BOUNDS.24
      ND=2                                                              BOUNDS.25
      NS=2                                                              BOUNDS.26
      WRITE(1) ND,NS,(LN(I),I=1,ND),((S(I,J),I=1,NS),J=1,NO)            BOUNDS.27
      GO TO 411                                                         BOUNDS.28
  410 CONTINUE                                                          BOUNDS.29
C     WRITE NON-LINEAR INFORNATION ON TAPE 41                           BOUNDS.30
      DO 304 I=1,2                                                      BOUNDS.31
      DO 304 J=1,2                                                      BOUNDS.32
      S(I,J)=SE(I,J)-S(I,J)                                             BOUNDS.33
  304 CONTINUE                                                          BOUNDS.34
      WRITE(41)NO,NS,(LN(I),I=1,NO),((S(I,J),I=1,NS),J=1,ND)            BOUNDS.35
  411 CONTINUE                                                          BOUNDS.36
      RETURN                                                            BOUNDS.37
      END                                                               BOUNDS.38
```

```
      SUBROUTINE TRIA(A,NEQ,MBAND)                                      TRIA.2
C                                                                       TRIA.3
C     ******************************************************************TRIA.4
C     TRIANGULIZE STIFFNESS MATRIX A OF AX=B                            TRIA.5
C     ******************************************************************TRIA.6
C                                                                       TRIA.7
      DIMENSION A(1)                                                    TRIA.8
      NE=NEQ-1                                                          TRIA.9
      MM=MBAND-1                                                        TRIA.10
      NN=NN*NEQ                                                         TRIA.11
      MK=NEQ-MM                                                         TRIA.12
      DO 301 N=1,NE                                                     TRIA.13
      NT=N-MK                                                           TRIA.14
      IF(NT .GT. 0) NM=NM-NEQ                                           TRIA.15
      IF(A(N) .EQ. 0.0) GO TO 301                                       TRIA.16
      L=N                                                               TRIA.17
      IL=N+NEQ                                                          TRIA.18
      IH=N+NM                                                           TRIA.19
      DO 302 I=IL,IH,NEQ                                                TRIA.20
      L=L+1                                                             TRIA.21
      J=L                                                               TRIA.22
      C=A(I)/A(N)                                                       TRIA.23
      DO 303 K=I,IH,NEQ                                                 TRIA.24
      A(J)=A(J)-C*A(K)                                                  TRIA.25
  303 J=J+NEQ                                                           TRIA.26
      A(I)=C                                                            TRIA.27
  302 CONTINUE                                                          TRIA.28
  301 CONTINUE                                                          TRIA.29
      RETURN                                                            TRIA.30
      END                                                               TRIA.31
```

```
      SUBROUTINE BACKS(A,B,NEQ,MBAND)                                   BACKS.2
C                                                                       BACKS.3
C     ****************************************************************BACKS.4
C      SOLVE EQUATIONS BY GAUSSIAN ELIMINATION                          BACKS.5
C     ****************************************************************BACKS.6
C                                                                       BACKS.7
      DIMENSION A(1),B(1)                                               BACKS.8
      MM=MBAND-1                                                        BACKS.9
      N=0                                                               BACKS.10
 1000 N=N+1                                                             BACKS.11
      C=B(N)                                                            BACKS.12
      IF(A(N) .NE. 0.0) B(N)=B(N)/A(N)                                  BACKS.13
      IF(N .EQ. NEQ) GO TO 401                                          BACKS.14
      L=N+1                                                             BACKS.15
      M=MIN0(NEQ,N+MM)                                                  BACKS.16
      M=N                                                               BACKS.17
      DO 301 I=L,M                                                      BACKS.18
      M=M+NEQ                                                           BACKS.19
  301 B(I)=B(I)-A(M)*C                                                  BACKS.20
      GO TO 1000                                                        BACKS.21
C                                                                       BACKS.22
  401 L=N                                                               BACKS.23
      N=N-1                                                             BACKS.24
      IF(N .EQ. 0) RETURN                                               BACKS.25
      M=MIN0(NEQ,N+MM)                                                  BACKS.26
      M=N                                                               BACKS.27
      DO 302 I=L,M                                                      BACKS.28
      M=M+NEQ                                                           BACKS.29
  302 B(N)=B(N)-A(M)*B(I)                                               BACKS.30
      GO TO 401                                                         BACKS.31
      END                                                               BACKS.32
```

```
      SUBROUTINE STRAIN(ID,X,Y,IX,DU,TEPS,DEPS,PEPS)                    STRAIN.2
C                                                                       STRAIN.3
C     ****************************************************************STRAIN.4
C      CALCULATE THE INCREMENTAL STRAIN,AND THEN TOTAL STRAIN OF SOIL ELSTRAIN.5
C     IN BOTH X,Y COORDS AND PRINCIPAL DIRECTION,AT CENTER OF ELEMENT   STRAIN.6
C     ****************************************************************STRAIN.7
C                                                                       STRAIN.8
      COMMON/ELPAR/NUMNP,NUMEL,NEQ,MBAND,KLIN                           STRAIN.9
      COMMON/TIME/JUMP,T,DT,NPRTM,NTAPE,KPRINT                          STRAIN.10
      DIMENSION HX(4),HY(4),B(3,8),LM(8)                                STRAIN.11
      DIMENSION ID(3,1),X(1),Y(1),IX(6,1),DU(1),TEPS(3,1),DEPS(3,1),    STRAIN.12
     1          PEPS(3,1)                                               STRAIN.13
      IF(JUMP .NE. 0) GO TO 401                                         STRAIN.14
C                                                                       STRAIN.15
C     INITIALIZATION                                                    STRAIN.16
      DO 301 I=1,3                                                      STRAIN.17
      DO 301 J=1,NUMEL                                                  STRAIN.18
      TEPS(I,J)=0.0                                                     STRAIN.19
      DEPS(I,J)=0.0                                                     STRAIN.20
      PEPS(I,J)=0.0                                                     STRAIN.21
  301 CONTINUE                                                          STRAIN.22
      DO 302 I=1,3                                                      STRAIN.23
      DO 302 J=1,8                                                      STRAIN.24
      B(I,J)=0.0                                                        STRAIN.25
  302 CONTINUE                                                          STRAIN.26
  401 CONTINUE                                                          STRAIN.27
      DO 303 N=1,NUMEL                                                  STRAIN.28
C                                                                       STRAIN.29
C     MATERIAL TYPE=NTYPE                                               STRAIN.30
      NTYPE=IX(5,N)                                                     STRAIN.31
      IF(NTYPE .NE. 1) GO TO 303                                        STRAIN.32
      DO 304 I=1,4                                                      STRAIN.33
      JJ=I+I                                                            STRAIN.34
      NODE=IX(I,N)                                                      STRAIN.35
      LM(JJ)=ID(2,NODE)                                                 STRAIN.36
      LM(JJ-1)=ID(1,NODE)                                               STRAIN.37
  304 CONTINUE                                                          STRAIN.38
      I=IX(1,N)                                                         STRAIN.39
      J=IX(2,N)                                                         STRAIN.40
      K=IX(3,N)                                                         STRAIN.41
      L=IX(4,N)                                                         STRAIN.42
C                                                                       STRAIN.43
C     DISPLACEMENT STRAIN TRANFORMATION MATRIX--B(3,8)                  STRAIN.44
C     AT POINT S=0,T=0 (N STRAIN -DISPLACEMENT MATRIX B(3,8)            STRAIN.45
      XI3=X(I)-X(K)                                                     STRAIN.46
      X24=X(J)-X(L)                                                     STRAIN.47
      YI3=Y(I)-Y(K)                                                     STRAIN.48
      Y24=Y(J)-Y(L)                                                     STRAIN.49
      XJ=XI3*Y24-X24*YI3                                                STRAIN.50
C                                                                       STRAIN.51
C     FORM DERIVATIVES OF HX()/DX=HX(),AND DERIVATIVES OF HY()/DY=HY()  STRAIN.52
      HX(1)=Y24/XJ                                                      STRAIN.53
      HX(2)=-YI3/XJ                                                     STRAIN.54
      HX(3)=-HX(1)                                                      STRAIN.55
            ....                                                        STRAIN.56
      HY(1)=-X24/XJ                                                     STRAIN.57
      HY(2)=XI3/XJ                                                      STRAIN.58
      HY(3)=-HY(1)                                                      STRAIN.59
      HY(4)=-HY(2)                                                      STRAIN.60
      DO 305 I=1,4                                                      STRAIN.61
      II=I+I                                                            STRAIN.62
      JJ=II-1                                                           STRAIN.63
      B(1,JJ)=HX(I)/12.0                                                STRAIN.64
      B(2,II)=HY(I)/12.0                                                STRAIN.65
      B(3,II)=HX(I)/12.0                                                STRAIN.66
      B(3,JJ)=HY(I)/12.0                                                STRAIN.67
  305 CONTINUE                                                          STRAIN.68
C                                                                       STRAIN.69
C     EVALUATION OF INCRENENTAL STRAIN-DEPS(3,N)                        STRAIN.70
      DO 306 I=1,3                                                      STRAIN.71
      DO 307 J=1,8                                                      STRAIN.72
      JJ=LM(J)                                                          STRAIN.73
      IF(JJ .EQ. 0) GO TO 307                                           STRAIN.74
      DEPS(I,N)=DEPS(I,N)+B(I,J)*DU(JJ)                                 STRAIN.75
  307 CONTINUE                                                          STRAIN.76
  306 CONTINUE                                                          STRAIN.77
C                                                                       STRAIN.78
C     ADD UP TOTAL STRAIN--TEPS(3,N)                                    STRAIN.79
      DO 308 I=1,3                                                      STRAIN.80
      TEPS(I,N)=TEPS(I,N)+DEPS(I,N)                                     STRAIN.81
  308 CONTINUE                                                          STRAIN.82
C                                                                       STRAIN.83
C     EVALUATE PRINCIPAL STRAIN-PEPS(I,N),AND                           STRAIN.84
C     MAX SHEAR STRAIN PEPS(3,N)                                        STRAIN.85
      DE=TEPS(1,N)-TEPS(2,N)                                            STRAIN.86
      IF(DE .EQ. 0) GO TO 402                                           STRAIN.87
      TAN=TEPS(3,N)/DE                                                  STRAIN.88
      THETA1=ATAN(TAN)/2.0                                              STRAIN.89
      THETA2=THETA1+1.5707963268                                        STRAIN.90
      TEMP1=TEPS(1,N)*COS(THETA1)*COS(THETA1)                           STRAIN.91
      TEMP1=TEMP1+TEPS(2,N)*SIN(THETA1)*SIN(THETA1)                     STRAIN.92
      TEMP1=TEMP1+TEPS(3,N)*SIN(THETA1)*COS(THETA1)                     STRAIN.93
      TEMP2=TEPS(1,N)*COS(THETA2)*COS(THETA2)                           STRAIN.94
      TEMP2=TEMP2+TEPS(2,N)*SIN(THETA2)*SIN(THETA2)                     STRAIN.95
      TEMP2=TEMP2+TEPS(3,N)*SIN(THETA2)*COS(THETA2)                     STRAIN.96
      PEPS(1,N)=AMAX1(TEMP1,TEMP2)                                      STRAIN.97
      PEPS(2,N)=AMIN1(TEMP1,TEMP2)                                      STRAIN.98
      PEPS(3,N)=PEPS(1,N)-PEPS(2,N)                                     STRAIN.99
      GO TO 303                                                         STRAIN.100
  402 CONTINUE                                                          STRAIN.101
      PEPS(1,N)=TEPS(1,N)                                               STRAIN.102
      PEPS(2,N)=TEPS(2,N)                                               STRAIN.103
      PEPS(3,N)=TEPS(3,N)                                               STRAIN.104
  303 CONTINUE                                                          STRAIN.105
      RETURN                                                            STRAIN.106
      END                                                               STRAIN.107
```

```
      SUBROUTINE STRESS(X,DU,DEPS,DSIG,SIG,PSIG)                        STRESS.2
C                                                                       STRESS.3
C     **********************************************************************STRESS.4
C     CALCULATE INCREMENTAL STRESS,AND TOTAL STRESS OF ALL ELEMENTS     STRESS.5
C     **********************************************************************STRESS.6
C                                                                       STRESS.7
      COMMON/ELPAR/NUMNP,NUMEL,NEQ,MBAND,KL(N                           STRESS.8
     0)MENSION X(6,1),DU(1),DEPS(3,1),DS(G(8,1),S(G(8,1),PS1G(4,1)     STRESS.9
      COMMON/7IME/JUMP,7,07,MPRTN,NTAPE,KPRINT                          STRESS.10
     0)MENSION LN(8),SS(138),S1(3,3),SA2(6,6),SA34(8,8),SA5(2,2)       STRESS.11
     01MENSION SS(138)                                                  STRESS.12
      EQU)VALENCE)SS,SS)                                                STRESS.13
      COMMON/NONL/NREAD                                                 STRESS.14
      IF(JUMP .NE. 0) GO 70 406                                         STRESS.15
C                                                                       STRESS.16
C     )N)T(L)ZAT)ON                                                     STRESS.17
      DO 301 I=1,8                                                      STRESS.18
      DO 301 J=1,NUMEL                                                  STRESS.19
      S)G)),J)=0.0                                                      STRESS.20
      DS1G(),J)=0.0                                                     STRESS.21
  301 CONT)NUE                                                          STRESS.22
  406 CONT)NUE                                                          STRESS.23
      REW(NO 41                                                         STRESS.24
      REW)ND 1                                                          STRESS.25
      DO 302 N=1,NUMEL                                                  STRESS.26
C                                                                       STRESS.27
C     OE7ERN)NE ELEMEN7 TYPE                                            STRESS.28
      NTYPE=)X(5,N)                                                     STRESS.29
      GO 70 (401,402,403,403,405),NTYPE                                 STRESS.30
C                                                                       STRESS.31
C     7YPE 1,SO(L ELEMENT                                               STRESS.32
  401 CONT(NUE                                                          STRESS.33
      )F(KL(N .EQ. 0) GO 70 411                                         STRESS.34
      )F(NREAD .EQ. 0) GO 70 411                                        STRESS.35
C     NON-L)NEAR CASE                                                   STRESS.36
      REAO(41) (SS(),I=1,19)                                            STRESS.37
      GO TO 412                                                         STRESS.38
  411 CON7INUE                                                          STRESS.39
      REAO(1) )SS()),(=1,I9)                                            STRESS.40
  412 CONT)NUE                                                          STRESS.41
      KK=7                                                              STRESS.42
C     SE7 UP S7RESS-STRA1N MATR(X-S1(3,3)                               STRESS.43
C                                                                       STRESS.44
      DO 352 I=1,3                                                      STRESS.45
      K)=KK+3*)                                                         STRESS.46
      DO 303 J=1,3                                                      STRESS.47
      JJ=K(+J                                                           STRESS.48
  303 S1(J,I)=SS(JI)                                                    STRESS.49
  352 CON7INUE                                                          STRESS.50
C                                                                       STRESS.51
C     CALCULA7E )NCREMENTAL S7RESS-DS(G(3,N),AND ADD UP TOTAL STRESS SIGSTRESS.52
      DO 304 I=1,3                                                      STRESS.53
      DO 305 J=1,3                                                      STRESS.54
  305 DS1G((,N)=DS1G(I,N)+S1((,J)*DEPS(J,N)                             STRESS.55
      S)G)(,N)=S(G((,N)+DS(G((,N)                                       STRESS.56
  304 CON7INUE                                                          STRESS.57
C     CALCULA7E PR(NCIPAL STRESSES,01RECT(ON,AND MAX. SHEAR             STRESS.58
      O=(S)G(1,N)-S1G(2,N))/2.0                                         STRESS.59
      S=(S(G(1,N)+S1G(2,N))/2.0                                         STRESS.60
      7AU=S(G(3,N)                                                      STRESS.61
      R=SQRT)O*O+7AU*TAU)                                               STRESS.62
      PS)G(1,N)=S+R                                                     STRESS.63
      PS(G(2,N)=S-R                                                     STRESS.64
      PS)G(3,N)=(PS(G(1,N)-PS1G(2,N))/2.0                               STRESS.65
      (F(O .NE. 0.0) GO 70 407                                          STRESS.66
      PS1G(4,N)=45.0                                                    STRESS.67
      GO TO 302                                                         STRESS.68
  407 CONT)NUE                                                          STRESS.69
      PH)2=2.0*S)G(3,N)/(S(G(1,N)-S(G(2,N))                             STRESS.70
      PH(2=A0S(PH(2)                                                    STRESS.71
      PS(G)4,N)=0.5*A7AN(PH)2)                                          STRESS.72
      PS1G)4,N)=PS)G(4,N)*57.29577                                      STRESS.73
      GO 70 302                                                         STRESS.74
C                                                                       STRESS.75
C     TYPE 2,BEAM,COLUMN ELEMENT                                        STRESS.76
  402 CON7)NUE                                                          STRESS.77
      )F)KL(N .EO. 0) GO 70 421                                         STRESS.78
      )F(NREAO .EO. 0) GO 70 421                                        STRESS.79
C     NON-L)NEAR CASE                                                   STRESS.80
      REAO(41) (SS((),I=1,80)                                           STRESS.81
      GO TO 422                                                         STRESS.82
  421 CON7INUE                                                          STRESS.83
      REAO(1) (SS)()),I=1,86)                                           STRESS.84
  422 CON7)NUE                                                          STRESS.85
      KK=38                                                             STRESS.86
C                                                                       STRESS.87
C     SET UP S7RESS-O)SPLACEMEN7 MATR)X-SA2)6,6)                        STRESS.88
      DO 306 I=1,6                                                      STRESS.89
      K(=KK+6*)                                                         STRESS.90
      DO 307 J=1,6                                                      STRESS.91
      J(=K)+J                                                           STRESS.92
  307 SA2(J,I)=SS(J()                                                   STRESS.93
  306 CONT(NUE                                                          STRESS.94
C                                                                       STRESS.95
C     SET UP LOCAT)ON OF MASS                                           STRESS.96
      DO 308 I=1,6                                                      STRESS.97
      LN(I)=1SS(2+I)                                                    STRESS.98
  308 CON7)NUE                                                          STRESS.99
C                                                                       STRESS.100
C     ADD UP F1XE0 END FORCES                                           STRESS.101
      (F(JUMP .NE. 0) GO 70 451                                         STRESS.102
      DO 351 I=1,6                                                      STRESS.103
      S)G((,N)=SS(80+()                                                 STRESS.104
  351 CON7(NUE                                                          STRESS.105
  451 CONTINUE                                                          STRESS.106
C                                                                       STRESS.107
C     CALCULA7E (NCREMENTAL STRESS-DS1G(6,N),AND 7OTAL S7RESS SIG(6,N)  STRESS.108
      DO 309 (=1,6                                                      STRESS.109
      DO 310 J=1,6                                                      STRESS.110
      JJ=LN(J)                                                          STRESS.111
      )F(JJ .EQ. 0) GO TO 310                                           STRESS.112
      DS(G((,N)=DS(G((,N)+SA2((,J)*DU(JJ)                               STRESS.113
  310 CON7)NUE                                                          STRESS.114
      S1G)),N)=S)G(1,N)+DS1G(1,N)                                       STRESS.115
  309 CON7)NUE                                                          STRESS.116
      GO TO 302                                                         STRESS.117
C                                                                       STRESS.118
C     TYPE 3,FR)C7(ONAL ELEMENT                                         STRESS.119
C     TYPE 4,EXPANS(ON JOIN7 ELEMENT                                    STRESS.120
  403 CONT(NUE                                                          STRESS.121
      )F(KL(N .EQ. 0) GO TO 431                                         STRESS.122
      (F)NREAD .EO. 0) GO 70 431                                        STRESS.123
      REAO(41) (SS((),I=1,138)                                          STRESS.124
      GO 70 432                                                         STRESS.125
  431 CON7INUE                                                          STRESS.126
      REAO(1) (SS((),(=1,138)                                           STRESS.127
  432 CONTINUE                                                          STRESS.128
      KK=66                                                             STRESS.129
C                                                                       STRESS.130
C     SE7 UP S7RESS-DISPLACEMEN7 MA7R)X SA34(8,8)                       STRESS.131
      DO 311 I=1,8                                                      STRESS.132
      K(=KK+8*(                                                         STRESS.133
      DO 312 J=1,8                                                      STRESS.134
      JI=K(+J                                                           STRESS.135
  312 SA34(J,()=SS(JI)                                                  STRESS.136
  311 CONT(NUE                                                          STRESS.137
C                                                                       STRESS.138
C     SE7 UP LOCA7(ON OF MASS                                           STRESS.139
      DO 313 I=1,8                                                      STRESS.140
      LN(I)=1SS(2+()                                                    STRESS.141
  313 CONT(NUE                                                          STRESS.142
C                                                                       STRESS.143
C     CALCULA7E )NCREMENTAL STRESS DS(G(8,N),AND 7OTAL STRESS S(G(8,N)  STRESS.144
      DO 314 (=1,8                                                      STRESS.145
      DO 315 J=1,8                                                      STRESS.146
      JJ=LN(J)                                                          STRESS.147
      )F(JJ .EQ. 0) GO 70 315                                           STRESS.148
      DS1G((,N)=DS(G(),N)+SA34((,J)*DU(JJ)                              STRESS.149
  315 CON7(NUE                                                          STRESS.150
      S1G((,N)=S)G(),N)+DS(G(1,N)                                       STRESS.151
  314 CON7(NUE                                                          STRESS.152
      GO TO 302                                                         STRESS.153
C                                                                       STRESS.154
C     TYPE 5, BOUNOARY ELEMEN7                                          STRESS.155
  405 CON7(NUE                                                          STRESS.156
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```
      IF(KLIN .EQ. 0) GO TO 441                                          STRESS.157
      IF(NREAD .EQ. 0) GO TO 441                                         STRESS.158
      READ(41) (SS(I),I=1,8)                                             STRESS.159
      GO TO 442                                                          STRESS.160
  441 CONTINUE                                                           STRESS.161
      READ(5) (SS(I),I=1,8)                                              STRESS.162
  442 CONTINUE                                                           STRESS.163
      KK=2                                                               STRESS.164
C                                                                        STRESS.165
C     SET UP STRESS--DISPLACEMENT MATRIX SA5(2,2)                        STRESS.166
      DO 316 I=1,2                                                       STRESS.167
      KI=KK*2**                                                          STRESS.168
      DO 317 J=I,2                                                       STRESS.169
      JI=KI+J                                                            STRESS.170
  317 SA5(J,I)=SS(JI)                                                    STRESS.171
  316 CONTINUE                                                           STRESS.172
C                                                                        STRESS.173
C     SET UP LOCATION OF MASS                                            STRESS.174
      DO 318 I=1,2                                                       STRESS.175
      LN(I)=ISS(2+I)                                                     STRESS.176
  318 CONTINUE                                                           STRESS.177
C                                                                        STRESS.178
C     CALCULATE INCREMSNTAL STRESS OSIG(2,N),AND TOTAL STRESS SIG(2,N)   STRESS.179
      DO 319 I=1,2                                                       STRESS.180
      DO 320 J=1,2                                                       STRESS.181
      JJ=LN(J)                                                           STRESS.182
      IF(JJ .EQ. 0) GO TO 320                                            STRESS.183
      OSIG(I,N)=OSIG(I,N)+SA5(I,J)*DUIJJ)                                STRESS.184
  320 CONTINUE                                                           STRESS.185
      SIG(I,N)=SIG(I,N)+OSIG(I,N)                                        STRESS.186
  319 CONTINUE                                                           STRESS.187
  302 CONTINUE                                                           STRESS.188
      RETURN                                                             STRESS.189
      END                                                                STRESS.190
```

```
      SUBROUTINE WADATA(NELW,INFW,NTW)                                   WADATA.2
C                                                                        WADATA.3
C     ***************************************************************  WADATA.4
C     INPUT DATA OF ELEMENTS AGAINST WALL FOR CALCULATE THE TOTAL FORCES WADATA.5
C     ***************************************************************  WADATA.6
C                                                                        WADATA.7
      COMMON/WATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NINTCV,THICKWADATA.8
     1,NPLAN                                                             WADATA.9
      COMMON/ELPAR/NUMNP,NUMEL,NEQ,MBAND,KLIN                            WADATA.10
      DIMENSION NELW(I(,INFW(NTW,1(                                      WADATA.11
C                                                                        WADATA.12
C     READ CONTROL INFORMATION                                           WADATA.13
      WRITE(6,502(                                                       WADATA.14
C                                                                        WADATA.15
C     READ IN ELEMENT DATA ON WALL, FROM TOP TO BOTTOM                   WADATA.16
      DO 301 I=1,NTW                                                     WADATA.17
      NN=3*NELW(I(                                                       WADATA.18
      READ 2,NW,(INFW(NW,II),II=1,NN)                                    WADATA.19
      WR(TE(6,102( NW                                                    WADATA.20
      WRITE(6,103) ((NFW(NW,II(,II=1,NN)                                 WADATA.21
  301 CONTINUE                                                           WADATA.22
    2 FORMAT(I5/I3I5))                                                   WADATA.23
  102 FORMAT(I9)                                                         WADATA.24
  103 FORMAT(18X,(5,19X,(5,19X,I5)                                       WADATA.25
  502 FORMAT(* WALL NO.*,3X,*ELEMENT NO.*,3X,*UPPER NODAL POINT NO.*,    WADATA.26
     I       3X,*LOWER NODAL POINT NO.*(                                 WADATA.27
      RETURN                                                             WADATA.28
      END                                                                WADATA.29
```

```
      SUBROUTINE WFORCE(Y,IX,SIG,NELW,INFW,WFX,YBAR,WFY,NTW(             WFORCE.2
C                                                                        WFORCE.3
C     ***************************************************************  WFORCE.4
C     CALCULATE THE TOTAL FORCES FX,FY,(LOCAL( ACTING ON THE WALL,       WFORCE.5
C     AND ITS LINE OF ACTION FROM THE BASE                               WFORCE.6
C     ***************************************************************  WFORCE.7
C                                                                        WFORCE.8
      COMMON/WATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NINTCY,THICKWFORCE.9
     I,NPLAN                                                            WFORCE.10
      DIMENSION Y(1),(X(6,1(,SIG(8,1(,NELW(1(,INFW(NTW,1(                WFORCE.11
      DIMENSION WFX(I(,YBAR(I),WFY(1),FNOD(8(                            WFORCE.12
      DO 301 I=1,NTW                                                     WFORCE.13
C                                                                        WFORCE.14
C     INITILIZATION                                                      WFORCE.15
      WNT=0.0                                                            WFORCE.16
      WFX(I(=0.0                                                         WFORCE.17
      WFY(I)=0.0                                                         WFORCE.18
      N=NELW(I(                                                          WFORCE.19
      NP=3*N                                                             WFORCE.20
      NL=NP-2                                                            WFORCE.21
C     LOWEST ELEMENT NO.                                                 WFORCE.22
      LNEL=INFW(I,NL)                                                    WFORCE.23
C     LOWEST NODAL POINT NO.                                             WFORCE.24
      LNOD=INFW(I,NP(                                                    WFORCE.25
      DO 302 J=1,N                                                       WFORCE.26
      JJ=3*IJ-1)+1                                                       WFORCE.27
      NEL=INFW(I,JJ(                                                     WFORCE.28
      NOD1=INFW(I,JJ+1(                                                  WFORCE.29
      NOD2=INFW(I,JJ+2)                                                  WFORCE.30
      YL=ABS(YINOD1)-YINOD2))                                            WFORCE.31
C                                                                        WFORCE.32
C     CHECK THE SEQUENCE OF NODE ON ELEMENT                              WFORCE.33
      DO 303 K=1,4                                                       WFORCE.34
      NOD=IX(K,NEL(                                                      WFORCE.35
      IF(NOD1 .NE. NOD) GO TO 401                                        WFORCE.36
      K2=K+K                                                             WFORCE.37
      K1=K2-1                                                            WFORCE.38
C                                                                        WFORCE.39
C     CHANGE THE CENTER STRESS TO NODAL FORCES IN CASE OF SOIL ELEMENT   WFORCE.40
      NTYPE=IX(5,NEL(                                                    WFORCE.41
      IF(NTYPE .EQ. 3( GO TO 402                                         WFORCE.42
      IF(SIG(1,NEL) .GE. 0.0( GO TO 403                                  WFORCE.43
      FNOD(K1)=0.5*THICK*YL*SIG(1,NEL)                                   WFORCE.44
      IF(K .EQ. 1 .OR. K .EQ. 2( GO TO 404                               WFORCE.45
      FNOD(K2(=-D.5*THICK*YL*SIG(3,NEL)                                  WFORCE.46
      GO TO 406                                                          WFORCE.47
  404 FNOD(K2(=0.5*THICK*YL*SIG(3,NEL(                                   WFORCE.48
      GO TO 406                                                          WFORCE.49
  403 FNOD(K1)=0.D                                                       WFORCE.50
      FNOD(K2)=D.O                                                       WFORCE.51
      GO TO 406                                                          WFORCE.52
  402 CONTINUE                                                           WFORCE.53
C                                                                        WFORCE.54
C     FRICTION ELEMENT AT WALL                                           WFORCE.55
      SIGN12=D.5*(SIG(2,NEL)+SIG(4,NEL))                                 WFORCE.56
      SIGN34=D.5*(SIG(6,NEL(+SIG(8,NEL))                                 WFORCE.57
      IF(SIGN12 .GT. D.D .AND. SIGN34 .LT. 0.0) GO TO 405                WFORCE.58
C                                                                        WFORCE.59
C     TENSION                                                            WFORCE.60
      FNOD(K1)=D.D                                                       WFORCE.61
      FNOD(K2(=D.O                                                       WFORCE.62
      GO TO 406                                                          WFORCE.63
  405 CONTINUE                                                           WFORCE.64
      FNOD(K1)=ABS(SIGN12(                                               WFORCE.65
      FNOD(K2)=-SIG(K1,NEL)                                              WFORCE.66
  406 CONTINUE                                                           WFORCE.67
      WFX(I(=WFX(I(+ABS(FNOD(KI()                                        WFORCE.68
      WNT=WNT+ABS(FNOD(K1)(*ABS(Y(NOO)-Y(LNOD((                          WFORCE.69
      WFY(I(=WFY(I)+FNOO(K2(                                             WFORCE.70
      GO TO 303                                                          WFORCE.71
  401 CONTINUE                                                           WFORCE.72
      IF(NOD2 .NE. NOD) GO TO 303                                        WFORCE.73
      K2=K+K                                                             WFORCE.74
      K1=K2-1                                                            WFORCE.75
      NTYPE=(X(5,NEL)                                                    WFORCE.76
      (F(NTYPE .EQ. 3) GO TO 407                                         WFORCE.77
      IF(SIG(1,NEL) .GE. D.0) GO TO 408                                  WFORCE.78
      FNOO(K1)=0.5*TH(CK*YL*S(G(1,NEL)                                   WFORCE.79
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      IF(K .EQ. I .OR. K .EQ. 2) GO TO 409                              WFORCE.80
      FNOD(K2)=-0.5*THICK*YL*SIG(3,NEL)                                 WFORCE.81
      GO TO 411                                                         WFORCE.82
  409 FNOD(K2)=0.5*THICK*YL*SIG(3,NEL)                                  WFORCE.83
      GO TO 411                                                         WFORCE.84
  408 CONTINUE                                                          WFORCE.85
      FNOD(K1)=0.0                                                      WFORCE.86
      FNOD(K2)=0.0                                                      WFORCE.87
      GO TO 411                                                         WFORCE.88
  407 CONTINUE                                                          WFORCE.89
C                                                                       WFORCE.90
C     FRICTION ELEMENT ON THE WALL                                      WFORCE.91
      SIGN12=0.5*(SIG(2,NEL)+SIG(4,NEL))                                WFORCE.92
      SIGN34=0.5*(SIG(6,NEL)+SIG(8,NEL))                                WFORCE.93
      IF(SIGN12 .GT. 0.0 .AND. SIGN34 .LT. 0.0) GO TO 410               WFORCE.94
C     TENSION                                                           WFORCE.95
      FNOD(K1)=0.0                                                      WFORCE.96
      FNOD(K2)=0.0                                                      WFORCE.97
      GO TO 411                                                         WFORCE.98
  410 CONTINUE                                                          WFORCE.99
      FNOD(K1)=ABS(SIGN12)                                              WFORCE.100
      FNOD(K2)=-SIG(K1,NEL)                                             WFORCE.101
  411 CONTINUE                                                          WFORCE.102
      WFX(I)=WFX(I)+ABS(FNOD(K1))                                       WFORCE.103
      WMT=WMT+ABS(FNOD(K1))*ABS(Y(NOD)-Y(LNOD))                         WFORCE.104
      WFY(I)=WFY(I)+FNOD(K2)                                            WFORCE.105
  303 CONTINUE                                                          WFORCE.106
  302 CONTINUE                                                          WFORCE.107
      IF(NTYPE .EQ. 3) GO TO 421                                        WFORCE.108
      IF(WFX(I) .EQ. 0.0) GO TO 412                                     WFORCE.109
      YBAR(I)=WMT/WFX(I)                                                WFORCE.110
      WFX(I)=WFX(I)*144.0                                               WFORCE.111
      WFY(I)=WFY(I)*144.0                                               WFORCE.112
      GO TO 301                                                         WFORCE.113
C                                                                       WFORCE.114
  412 CONTINUE                                                          WFORCE.115
      YBAR(I)=0.0                                                       WFORCE.116
      GO TO 301                                                         WFORCE.117
C     CASE OF FRICTION ELEMENT                                          WFORCE.118
  421 CONTINUE                                                          WFORCE.119
      IF(WFX(I) .EQ. 0) GO TO 422                                       WFORCE.120
      YBAR(I)=WMT/WFX(I)                                                WFORCE.121
      GO TO 301                                                         WFORCE.122
  422 CONTINUE                                                          WFORCE.123
      YBAR(I)=0.0                                                       WFORCE.124
  301 CONTINUE                                                          WFORCE.125
      RETURN                                                            WFORCE.126
      END
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      SUBROUTINE PRINTR(IO,IX,U,V,ACC,TEPS,PEPS,SIG,PSIG,WFX,YBAR,WFY,  PRINTR.2
     1           NPASS,NIND,HSIG,NTW,NUMELE)                            PRINTR.3
C                                                                       PRINTR.4
C     ****************************************************************PRINTR.5
C     PRINT THE CALCULATED RESULTS AND STORE ON TAPE 2 FOR PLOTTING     PRINTR.6
C     ****************************************************************PRINTR.7
C                                                                       PRINTR.8
      COMMON/NATER/NUMATS,NUMATC,NUMATF,NUMATE,NUNATB,NUMGE,NINTCV,THICKPRINTR.9
     1,NPLAN                                                            PRINTR.10
      COMMON/ELPAR/NUMNP,NUNEL,NEQ,NBAND,KLIN                           PRINTR.11
      COMMON/TIME/JUMP,T,DT,NPRTM,NTAPE,KPRINT                          PRINTR.12
      COMMON/ABS/UGXT,UGYT,VGXT,VGYT,OACCX,OACCY                        PRINTR.13
      DIMENSION ID(3,1),IX(6,1),U(1),V(1),ACC(1),TEPS(3,1),PEPS(3,1),   PRINTR.14
     1          SIG(8,1),PSIG(4,1),NPASS(1),NIND(1),WFX(1),YBAR(1),     PRINTR.15
     2          WFY(1),D(9)                                             PRINTR.16
      COMMON/SPEC1L/ISTOP                                               PRINTR.17
      DIMENSION HSIG(9,NUMELE)                                          PRINTR.18
C                                                                       PRINTR.19
C                                                                       PRINTR.20
C     DETERMINE TO BE PRINT OR NOT                                      PRINTR.21
      IF(JUMP .EQ. 1) KPRINT=NPRTM                                      PRINTR.22
      IF(JUMP .EQ. 1) GO TO 401                                         PRINTR.23
      IF(ISTOP .EQ. 1) GO TO 401                                        PRINTR.24
      IF(JUMP .NE. KPRINT) GO TO 411                                    PRINTR.25
      ISTOP=2                                                           PRINTR.26
      KPRINT=KPRINT+NPRTM                                               PRINTR.27
C     STATIC RESULT                                                     PRINTR.28
      IF(JUMP .NE. 0) GO TO 401                                         PRINTR.29
      DO 351 I=1,NUMEL                                                  PRINTR.30
      NPASS(I)=0                                                        PRINTR.31
  351 NIND(I)=0                                                         PRINTR.32
      DO 352 N=1,NUMEL                                                  PRINTR.33
      DO 352 I=1,9                                                      PRINTR.34
      HSIG(I,N)=0.0                                                     PRINTR.35
  352 CONTINUE                                                          PRINTR.36
      WRITE(6,501)                                                      PRINTR.37
      GO TO 402                                                         PRINTR.38
  401 CONTINUE                                                          PRINTR.39
      WRITE(6,502)                                                      PRINTR.40
  402 CONTINUE                                                          PRINTR.41
C                                                                       PRINTR.42
C     NODAL POINT DISPLACEMENT,VELOCITY,ACCELERATION                    PRINTR.43
      WRITE(6,503)                                                      PRINTR.44
      WRITE(6,101) JUMP,T                                               PRINTR.45
C                                                                       PRINTR.46
C     GROUND DISPLACEMENT,VELOCITY,ACCELERATION                         PRINTR.47
      IF(JUMP .EQ. 0) GO TO 405                                         PRINTR.48
      WRITE(6,104) UGXT,UGYT,VGXT,VGYT,OACCX,OACCY                      PRINTR.49
  405 CONTINUE                                                          PRINTR.50
      DO 301 N=1,NUMNP                                                  PRINTR.51
      DO 302 I=1,9                                                      PRINTR.52
  302 D(I)=0.0                                                          PRINTR.53
      DO 303 I=1,3                                                      PRINTR.54
      M=ID(I,N)                                                         PRINTR.55
      IF(M .EQ. 0) GO TO 303                                            PRINTR.56
      D(I)=U(M)                                                         PRINTR.57
      D(I+3)=V(M)                                                       PRINTR.58
      D(I+6)=ACC(M)                                                     PRINTR.59
  303 CONTINUE                                                          PRINTR.60
      WRITE(6,102) N,(D(I),I=1,9)                                       PRINTR.61
  301 CONTINUE                                                          PRINTR.62
C                                                                       PRINTR.63
C     STRESS,STRAIN AT CENTER OF SOIL ELEMENT                           PRINTR.64
      WRITE(6,504)                                                      PRINTR.65
  411 CONTINUE                                                          PRINTR.66
      DO 304 N=1,NUMEL                                                  PRINTR.67
      NTYPE=IX(5,N)                                                     PRINTR.68
      IF(NTYPE .NE. 1) GO TO 304                                        PRINTR.69
      DO 305 I=1,9                                                      PRINTR.70
  305 D(I)=0.0                                                          PRINTR.71
      DO 306 I=1,3                                                      PRINTR.72
      HSIG(I,N)=SIG(I,N)                                                PRINTR.73
      D(I)=SIG(I,N)                                                     PRINTR.74
      D(I+3)=TEPS(I,N)                                                  PRINTR.75
      D(I+6)=PEPS(I,N)                                                  PRINTR.76
  306 CONTINUE                                                          PRINTR.77
      HSIG(9,N)=FLOAT(NPASS(N))                                         PRINTR.78
      IF(ISTOP .EQ. 1 .OR. JUMP .EQ. 1) GO TO 416                       PRINTR.79
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      IF(ISTOP .NE. 2) GO TO 304                                        PRINTR.80
  416 CONTINUE                                                          PRINTR.81
      WRITE(6,102) N,(O(I),I=1,9)                                       PRINTR.82
  304 CONTINUE                                                          PRINTR.83
      IF(ISTOP .EO. 1 .OR. JUMP .EQ. 11 GO TO 417                       PRINTR.84
      IF(ISTOP .NE. 2) GO TO 412                                        PRINTR.85
  417 CONTINUE                                                          PRINTR.86
      WRITE(6,509)                                                      PRINTR.87
      DO 321 N=1,NUMEL                                                  PRINTR.88
      NTYPE=IX(5,N)                                                     PRINTR.89
      IF(NTYPE .NE. 1) GO TO 321                                        PRINTR.90
      WRITE(6,105) N,(PSIG(I,N),I=1,4I,NPASS(NI                         PRINTR.91
  321 CONTINUE                                                          PRINTR.92
  412 CONTINUE                                                          PRINTR.93
      IF(NUMATC .EQ. 0) GO TO 406                                       PRINTR.94
      IF(ISTOP .EO. 1 .OR. JUMP .EQ. 1) GO TO 418                       PRINTR.95
      IF(ISTOP .NE. 2) GO TO 413                                        PRINTR.96
  418 CONTINUE                                                          PRINTR.97
C                                                                       PRINTR.98
C     END FORCES OF BEAM,COLUMN                                         PRINTR.99
      WRITE(6,505)                                                      PRINTR.100
  413 CONTINUE                                                          PRINTR.101
      DO 307 N=1,NUMEL                                                  PRINTR.102
      NTYPE=IX(5,N)                                                     PRINTR.103
      IF(NTYPE .NE. 2) GO TO 307                                        PRINTR.104
      DO 353 I=1,6                                                      PRINTR.105
      HSIG(I,N)=SIG(I,NI                                                PRINTR.106
  353 CONTINUE                                                          PRINTR.107
      HSIG(9,NI=FLOAT(NINDINII                                          PRINTR.108
      DO 308 I=1,4                                                      PRINTR.109
  308 D(I)=0.0                                                          PRINTR.110
      O(1I=SIG(4,NI                                                     PRINTR.111
      D(2)=SIG(2,N)                                                     PRINTR.112
      O(3)=SIG(3,N)                                                     PRINTR.113
      D(4)=SIG(6,N)                                                     PRINTR.114
      IF(ISTOP .EO. 1 .OR. JUMP .EQ. 11 GO TO 419                       PRINTR.115
      IF(ISTOP .ME. 2) GO TO 307                                        PRINTR.116
  419 CONTINUE                                                          PRINTR.117
      WRITE(6,102) N,(O(I),I=1,4I,HSIG(9,N)                             PRINTR.118
  307 CONTINUE                                                          PRINTR.119
  406 CONTINUE                                                          PRINTR.120
      IF(NUMATF .EO. 0 .ANO. NUMATE .EO. 0) GO TO 407                   PRINTR.121
      IF(ISTOP .EQ. 1 .OR. JUMP .EQ. 11 GO TO 420                       PRINTR.122
      IF(ISTOP .NE. 2) GO TO 414                                        PRINTR.123
  420 CONTINUE                                                          PRINTR.124
C                                                                       PRINTR.125
C     NODAL FORCE AT FRICTIONAL,AND EXPANSION JOINT ELEMENT             PRINTR.126
      WRITE(6,506)                                                      PRINTR.127
  414 CONTINUE                                                          PRINTR.128
      DO 358 N=1,NUMEL                                                  PRINTR.129
      NTYPE=IX(5,N)                                                     PRINTR.130
      IF(NTYPE .NE. 3 .AND. NTYPE ,NE. 4I GO TO 358                     PRINTR.131
      N1=IX(1,N)                                                        PRINTR.132
      N2=IXI2,NI                                                        PRINTR.133
      N3=IX(3,NI                                                        PRINTR.134
      N4=IX(4,N)                                                        PRINTR.135
      DO 309 I=1,8                                                      PRINTR.136
  309 O(I)=0.0                                                          PRINTR.137
      DO 310 I=1,8                                                      PRINTR.138
      HSIG(I,NI=SIG(I,N)                                                PRINTR.139
  310 D(I)=SIG(1,N)                                                     PRINTR.140
      HSIG(9,N)=FLOAT(NINO(N)I                                          PRINTR.141
      IF(ISTOP .EO. 1 .OR. JUMP .EO. 11 GO TO 421                       PRINTR.142
      IF(ISTOP .NE. 2) GO TO 358                                        PRINTR.143
  421 CONTINUE                                                          PRINTR.144
      WRITE(6,103) N,N1,N2,N3,N4,(OIII,I=1,8I                           PRINTR.145
  358 CONTINUE                                                          PRINTR.146
  407 CONTINUE                                                          PRINTR.147
      IF(NUMAT8 .EQ. 0I GO TO 408                                       PRINTR.148
      IF(ISTOP .EO. 1 .OR. JUMP .EO. 11 GO TO 422                       PRINTR.149
      IF(ISTOP .NE. 2) GO TO 415                                        PRINTR.150
  422 CONTINUE                                                          PRINTR.151
C                                                                       PRINTR.152
C     AXIAL FORCE AT BOUNDARY SPRING                                    PRINTR.153
      WRITE(6,50T)                                                      PRINTR.154
  415 CONTINUE                                                          PRINTR.155
      DO 311 N=1,NUMEL                                                  PRINTR.156
      NTYPE=IX(5,N)                                                     PRINTR.157
      IF(NTYPE .NE. 5) GO TO 311                                        PRINTR.158
      D(1)=SIG(2,N)                                                     PRINTR.159
      HSIG(1,N)=SIG(2,N)                                                PRINTR.160
      HSIG(9,NI=FLOAT(NIND(N))                                          PRINTR.161
      IF(ISTOP .EO. 1 .OR. JUMP .EO. 11 GO TO 423                       PRINTR.162
      IF(ISTOP .NE. 2I GO TO 311                                        PRINTR.163
  423 CONTINUE                                                          PRINTR.164
      WRITE(6,102) N,O(1)                                               PRINTR.165
  311 CONTINUE                                                          PRINTR.166
  408 CONTINUE                                                          PRINTR.167
C                                                                       PRINTR.168
C     FORCES AGAINST THE WALL                                           PRINTR.169
      IF(NTW .EQ. 0) GO TO 410                                          PRINTR.170
      IF(ISTOP .EO. 1 .OR. JUMP .EQ. 11 GO TO 424                       PRINTR.1T1
      IF(ISTOP .NE. 2I GO TO 410                                        PRINTR.1T2
  424 CONTINUE                                                          PRINTR.1T3
      WRITE(6,508)                                                      PRINTR.1T4
      DO 312 N=1,NTW                                                    PRINTR.1T5
      WRITE(6,102) N,WFX(NI,YBAR(NI,WFY(NI                              PRINTR.1T6
  312 CONTINUE                                                          PRINTR.1T7
C                                                                       PRINTR.1T8
C     WRITE INFORMATION ON TAPE 2 FOR PLOTTING                          PRINTR.1T9
  410 CONTINUE                                                          PRINTR.180
      IF(JUMP .EQ. 0) GO TO 403                                         PRINTR.181
      KJJ=(JUMP/NTAPEI*NTAPE                                            PRINTR.182
      IF(KJJ .ME. JUMPI GO TO 404                                       PRINTR.183
  403 CONTINUE                                                          PRINTR.184
      WRITE(21) (U(I),I=1,NEQI,(ACC(II,I=1,NEQI                        PRINTR.185
      WRITE(22I ((HSIG(I,N),I=1,9I,N=1,NUMEL)                          PRINTR.186
      IF(NTW .EQ. 0I GO TO 404                                          PRINTR.187
      WRITE(23I (WFX(I),YBAR(I),WFY(II,I=1,NTWI                         PRINTR.188
  404 CONTINUE                                                          PRINTR.189
      ISTOP=0                                                           PRINTR.190
      RETURN                                                            PRINTR.191
  101 FORMAT(I5,F10.4)                                                  PRINTR.192
  102 FORMAT(15X,I5,9E12.4I                                             PRINTR.193
  103 FORMAT(15X,I8,4I3,8E11.3I                                         PRINTR.194
  104 FORMAT(* GROUND MOTION*,6X,2E12.4,12X,2E12.4,12X,2E12.4I          PRINTR.195
  105 FORMAT(15X,I5,4E12.4,110)                                         PRINTR.196
  501 FORMAT1*1STATIC ANALYSIS RESULT*//I                               PRINTR.197
  502 FORMAT(*1DYNAMIC ANALYSIS RESULT*//I                              PRINTR.198
  503 FORMAT(* RELATIVE DISP-U,VELOC-V,TOTAL ACCEL-ACC*//               PRINTR.199
     1       * TIME       TIME NODE*,                                   PRINTR.200
     2       4X,*     U-X*,4X,*     U-Y*,4X,*    U-ZZ*,               PRINTR.201
     3       4X,*     V-X*,4X,*     V-Y*,4X,*    V-ZZ*,               PRINTR.202
     4       4X,*   ACC-X*,4X,*   ACC-Y*,4X,*  ACC-ZZ*/               PRINTR.203
     5       * STEP        SEC  NO.*,                                  PRINTR.204
     6       4X,*    INCH*,4X,*    INCH*,4X,*    RAD.*,               PRINTR.205
     T       4X,*INCH/SEC*,4X,*INCH/SEC*,4X,*RAD./SEC*,                PRINTR.206
     8       4X,* IN/S..2*,4X,* IN/S..2*,4X,*RAO/S..2*//I              PRINTR.20T
  504 FORMAT(15X,* STRESS,STRAIN AT THE CENTER OF SOIL ELEMENT*/        PRINTR.208
     1   15X,* SIGX ,SIGY , SIGXY-THE STRESSES*/                       PRINTR.209
     2   15X,* TEPSX,TEPSY,TEPSXY-THE STRAINS IN X,Y COOROS*/          PRINTR.210
     3   15X,* PEPS1,PEPS2,PEPS12-THE PRINCIPAL STRAINS,MAX, SHEAR*//  PRINTR.211
     4       *                    ELEM*,                               PRINTR.212
     5     6X,* SIGX*,6X,*  SIGY*,6X,* SIGXY*,                         PRINTR.213
     6     6X,* TEPSX*,6X,* TEPSY*,6X,*TEPSXY*,                        PRINTR.214
     T     6X,* PEPS1*,6X,* PEPS2*,6X,*PEPS12*/                        PRINTR.215
     8       *                    NO.*,                               PRINTR.216
     9     6X,*   KSI*,6X,*   KSI*,6X,*   KSI*//I                    PRINTR.217
  505 FORMAT(15X,* BEAM,COLUMN FORCES,MOMENT*//                         PRINTR.218
     1       *                    ELEM*,                               PRINTR.219
     2     5X,*  AXIAL*,5X,*  SHEAR*,5X,*BENDING*,5X,*BENDING*,5X,*YIELD*PRINTR.220
     3       /*                   NO.*,                               PRINTR.221
     4     5X,*    KIP*,5X,*    KIP*,5X,*M3,K-IN*,5X,*M6,K-IN*//)      PRINTR.222
  506 FORMAT(15X,* NODAL FORCES AT FRICTION AND EXPANSION ELEMENT*/     PRINTR.223
     1       *                    ELEMENT NODAL ORDER*,                PRINTR.224
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     2    8X,* H1*,8X,* V1*,8X,* HZ*,8X,* V2*,                                PRINTR.225
     3    8X,* H3*,8X,* Y3*,8X,* H4*,8X,* V4* /                               PRINTR.226
     4      *                        NO. N1 N2 N3 N4*,8X,*KIP*//)              PRINTR.227
  507 FORMAT(15X,* AXIAL FORCES AT BOUNDARY SPRING*//                         PRINTR.228
     1      15X,* ELEMENT*,6X,* AXIAL*/                                       PRINTR.229
     2      15X,*     NO.*,6X,*   KIP*/)                                      PRINTR.230
  508 FORMAT(15X,* TOTAL FORCES ACTING ON THE WALL*/                          PRINTR.231
     1   15X,* FORCE PERPEDICULAR TO WALL..X-FORCE*/                         PRINTR.232
     2   15X,* FORCE PARALLEL TO THE WALL...Y-FORCE*/                        PRINTR.233
     3   15X,* LINE OF ACTION FROM THE BASE..YBAR*//                         PRINTR.234
     4   15X,* WALL*,4X,* X-FORCE*,TX,* YBAR*,4X,* Y-FORCE*/                 PRINTR.235
     5   15X,*  NO.*,4X,*     KIP*,TX,*   FT*,4X,*     KIP*//)               PRINTR.236
  509 FORMAT(15X,* PSIG1,PSIG2,PSIG3,PSIG4,-PRINCIPAL STRESSES,MAX.SHEARPRINTR.23T
     1PRINCIPAL DIRECTION*/                                                  PRINTR.238
     2   15X,* NPASS=0 ELASTIC, 1 ACTIVE FAILURE, 2 PASSIVE FAILURE*//       PRINTR.239
     3     *                    ELEMENT*.                                    PRINTR.240
     4    6X,* PSIG1*,6X,* PSIG2*,6X,* PSIG3*,6X,* PSIG4*,4X,* NPASS*//)PRINTR.241
      END                                                                    PRINTR.242
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      SUBROUTINE NTSTIFIX,Y,PARASO,PARACO,PARAFR,PARAEX,PARABO,COPROP,      NTSTIF.2
     1K2S,CMP,IX,I8C,SLV,C,AEN,U,V,DU,TEPS,DEPS,PEPS,OSIG,SIG,PSIG,         NTSTIF.3
     2NPASS,NIND,SY,GS,NEO,MBAND,NUMEL,KLIN)                                NTSTIF.4
C     ********************************************************************NTSTIF.5
C     FORM NON-LINEAR TOTAL TANGENT STIFFNESS MATRIX AEN(NEQ,MBANDI         NTSTIF.6
C     ********************************************************************NTSTIF.7
      COMMON/ELM/LN(8),ASA(8,8)                                             NTSTIF.8
      COMMON/NELEM/N                                                        NTSTIF.9
      DIMENSION X(1),Y(1),PARASO(8,1),PARACO(5,1),PARAFR(4,1I,              NTSTIF.10
     1PARAEX14,1),PARABDI2,1),K2SI2D,1),CMPI9,1),IXI6,1),I8CI4,1),U(1),     NTSTIF.11
     2V(1),DU(1),TEPS(3,1),OEPSI3,1),PEPSI3,1),DSIG(8,1),SIG(8,1),          NTSTIF.12
     3PSIGI4,1),SYI6,6),C(5,1),NPASS(1I,NIND(1),AEN(NEQ,1)                  NTSTIF.13
      DIMENSION SS(138),SA2(6,6),SA4I8,8),UEI4),YE(8),DTU(8),F(8)           NTSTIF.14
      DIMENSION XXI4),YYI4),AC(3),BC13),CC(3)                               NTSTIF.15
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                              NTSTIF.16
      DIMENSION COPROPI3,1),SLV(1)                                          NTSTIF.1T
      COMMON/NONL/NREAD                                                     NTSTIF.18
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATE,NUMATB,NUMGE,NINTCV,THICKNTSTIF.19
     1,NPLAN                                                                NTSTIF.20
      EQUIVALENCE(SS,ISS)                                                   NTSTIF.21
      DIMENSION ISS(138)                                                    NTSTIF.22
      DIMENSION SL(6,6)                                                     NTSTIF.23
      COMMON/ELASTC/SEI8,8)                                                 NTSTIF.24
      REAL K2S                                                              NTSTIF.25
C                                                                           NTSTIF.26
C     IF LINEAR ANALYSIS,GO BACK                                            NTSTIF.2T
      NREAD=1                                                               NTSTIF.28
      IF(KLIN .EQ. D)RETURN                                                 NTSTIF.29
C     INITILIZATION                                                         NTSTIF.30
      DD 351 I=1,5                                                          NTSTIF.31
      DD 351 J=1,NUMEL                                                      NTSTIF.32
  351 CII,JJ=D.D                                                            NTSTIF.33
      DD 34T I=1,8                                                          NTSTIF.34
      DD 347 J=1,8                                                          NTSTIF.35
      SEII,JJ=D.D                                                           NTSTIF.36
  34T CONTINUE                                                              NTSTIF.3T
      NYIELD=D                                                              NTSTIF.38
C                                                                           NTSTIF.39
C     READ TOTAL ELASTIC STIFFNESS FROM TAPE 3,AND PUT INTO--AEN            NTSTIF.40
      REWIND 3                                                              NTSTIF.41
      READI3) ((AEN(I,J),I=1,NEQ),J=1,MBAND)                               NTSTIF.42
      REWIND 41                                                             NTSTIF.43
      REWIND 1                                                              NTSTIF.44
C                                                                           NTSTIF.45
C     CHECK YIELD CONDITION OF ELEMENTS,ONE BY ONE                          NTSTIF.46
      DO 3D2 N=1,NUMEL                                                      NTSTIF.47
      NTYPE=IX(5,N)                                                         NTSTIF.48
      MATYPE=IXI6,N)                                                        NTSTIF.49
      GD TO (401,4D2,403,403,405),NTYPE                                     NTSTIF.5D
  401 CONTINUE                                                              NTSTIF.51
C                                                                           NTSTIF.52
C     TYPE 1,SOIL ELEMENT                                                   NTSTIF.53
      CALL SOILNE(PARASDI1,MATYPE),K2SI1,NATYPE),TEPS(1,N),DEPSI1,N),       NTSTIF.54
     1PEPSI1,N),OSIGI1,N),SIGI1,N),PSIG(1,N),SY,GS,SIGMST,NINOIN),          NTSTIF.55
     2NPASSIN))                                                             NTSTIF.56
      READ(1) (SSII),I=1,19)                                                NTSTIF.57
      KK=7                                                                  NTSTIF.58
      DO 341 I=1,3                                                          NTSTIF.59
      KI=KK+3*I                                                             NTSTIF.6D
      DO 342 J=1,3                                                          NTSTIF.61
      JI=KI+J                                                               NTSTIF.62
  342 SE(J,I)=SSIJI)                                                        NTSTIF.63
  341 CONTINUE                                                              NTSTIF.64
C                                                                           NTSTIF.65
C     CHECK IF IT IS YIELD                                                  NTSTIF.66
      IF(NINO(N) .NE. D) GO TO 321                                          NTSTIF.6T
      WRITE(41) (SSII),I=1,19)                                              NTSTIF.68
      GO TO 302                                                             NTSTIF.69
  321 CONTINUE                                                              NTSTIF.TD
C                                                                           NTSTIF.71
C     LOCATION OF MASS                                                      NTSTIF.72
      DO 303 I=1,8                                                          NTSTIF.73
  303 LMII)=ISS(2*I)                                                        NTSTIF.T4
      DO 304 I=1,4                                                          NTSTIF.T5
      NODE=IXII,N)                                                          NTSTIF.76
      XX(I)=X(NODE)                                                         NTSTIF.TT
      YY(I)=Y(NODE)                                                         NTSTIF.78
  304 CONTINUE                                                              NTSTIF.T9
      IF(NIND(NI .EQ. 2) GO TO 451                                          NTSTIF.80
C                                                                           NTSTIF.81
C     FORM TANGENT STIFFNESS,BY SUBTRACTING ASA FROM AEN                    NTSTIF.82
      CALL QUADS(XX,YY,CII,N),SY,NIND(N)I                                   NTSTIF.83
      CALL SUBTRC(AEN,NEQI                                                  NTSTIF.84
      GO TO 3D2                                                             NTSTIF.85
  451 CONTINUE                                                              NTSTIF.86
C                                                                           NTSTIF.8T
C     CASE OF CHANGE STIFFNESS BUT NOT YIELD AFTER STATIC NANLYSIS          NTSTIF.88
      ANU=PARASO(3,MATYPE)                                                  NTSTIF.89
      IF(NPLAN .EO. 1) GO TO 452                                            NTSTIF.90
C                                                                           NTSTIF.91
C     PLANE STRAIN                                                          NTSTIF.92
      B1=2.D*(1.0-ANU)                                                      NTSTIF.93
      B2=1.0-2.0*ANU                                                        NTSTIF.94
      C(1,N)=GS*B1/B2                                                       NTSTIF.95
      C(2,N)=GS*2.D*ANU/B2                                                  NTSTIF.96
      C(3,N)=GS                                                             NTSTIF.9T
      GO TO 453                                                             NTSTIF.98
C                                                                           NTSTIF.99
C     PLANE STRESS                                                          NTSTIF.100
  452 CONTINUE                                                              NTSTIF.101
      B1=1.0-ANU                                                            NTSTIF.102
      C(1,N)=GS*2.0/B1                                                      NTSTIF.103
      C(2,N)=GS*2.0*ANU/B1                                                  NTSTIF.104
      C(3,N)=GS                                                             NTSTIF.105
  453 CONTINUE                                                              NTSTIF.106
      CALL QUADS(XX,YY,C(I,N),SY,NIND(N))                                   NTSTIF.10T
      CALL SUBTRC(AEN,NEO)                                                  NTSTIF.108
      NYIELD=2                                                              NTSTIF.109
      GO TO 3D2                                                             NTSTIF.110
C                                                                           NTSTIF.111
C     TYPE 2,BEAM,COLUMN ELEMENT                                            NTSTIF.112
  402 CONTINUE                                                              NTSTIF.113
C                                                                           NTSTIF.114
C     READ ELASTIC INFORMATION FROM TAPES 1                                 NTSTIF.115
      READ(1) (SSII),I=1,8D)                                                NTSTIF.116
C                                                                           NTSTIF.11T
C     IF ELASTIC BEAM,GO BACK                                               NTSTIF.118
      IF(PARACDI1,MATYPE) .NE. PARACO(2,NATYPE)) GO TO 322                  NTSTIF.119
      WRITE(41) (SS(I),I=1,80I                                              NTSTIF.12D
      GO TO 302                                                             NTSTIF.121
  322 CONTINUE                                                              NTSTIF.122
C                                                                           NTSTIF.123
C     LOCATION OF MASS                                                      NTSTIF.124
C     FORM ELASTIC DISPLACEMENT(GLOBAL)-STRESSILOCAL) MATRIX-SA2(6,6)       NTSTIF.125
      KK=38                                                                 NTSTIF.126
      DO 354 I=1,6                                                          NTSTIF.127
      KI=KK+6*I                                                             NTSTIF.128
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      DO 305 J=1,6                                                      NTSTIF.129
      JI=KI+J                                                           NTSTIF.130
  305 SA2(J,I)=SS(JI)                                                   NTSTIF.131
  354 CONTINUE                                                          NTSTIF.132
      DO 346 I=1,6                                                      NTSTIF.133
      DO 346 J=1,6                                                      NTSTIF.134
      SE(I,J)=SA2(I,J)                                                  NTSTIF.135
  346 CONTINUE                                                          NTSTIF.136
C     FORM DISPLACEMENT STRESS MATRIX,LOCAL--SL(6,6(                    NTSTIF.137
      KK=2                                                              NTSTIF.138
      DO 355 I=1,6                                                      NTSTIF.139
      K(=KK+6*I                                                         NTSTIF.140
      DO 356 J=1,6                                                      NTSTIF.141
      JI=KI+J                                                           NTSTIF.142
  356 SL(J,I)=SS(JI)                                                    NTSTIF.143
  355 CONTINUE                                                          NTSTIF.144
      DO 307 I=1,6                                                      NTSTIF.145
  307 LM(I)=(SS(2*I)                                                    NTSTIF.146
      LM(7)=0                                                           NTSTIF.147
      LM(8)=0                                                           NTSTIF.148
C                                                                       NTSTIF.149
C     FIND INCREMENTAL NODAL DISPLACEMENT                               NTSTIF.150
      DO 308 I=1,6                                                      NTSTIF.151
      JJ=LM(I)                                                          NTSTIF.152
      IF(JJ .NE. 0) GO TO 406                                           NTSTIF.153
      DTU(I)=0.0                                                        NTSTIF.154
      GO TO 407                                                         NTSTIF.155
  406 DTU(I)=DU(JJ)                                                     NTSTIF.156
  407 CONTINUE                                                          NTSTIF.157
      F(I)=SIG(I,N)-OSIG(I,N)                                           NTSTIF.158
  308 CONTINUE                                                          NTSTIF.159
C                                                                       NTSTIF.160
C     CALCULATE COEFFICIENT OF YIELD FCTN                               NTSTIF.161
      NINT=IBC(4,N)                                                     NTSTIF.162
      AC(1)=1.0                                                         NTSTIF.163
      BC(1)=0.0                                                         NTSTIF.164
      CC(1)=-CMP(2,NINT)/(CMP(5,NINT))                                  NTSTIF.165
      AC(2)=1.0-CMP(3,N(NT)/CMP(6,NINT)                                 NTST'F.166
      BC(2)=CMP(2,NINT)/CMP(5,NINT)-1.0                                 NTSTIF.167
      CC(2)=-BC(2)-AC(2)                                                NTSTIF.168
      AC(3)=1.0-CMP(9,NINT)/CMP(6,NINT)                                 NTSTIF.169
      BC(3)=CMP(8,N(NT)/CMP(5,NINT(-1.0                                 NTSTIF.170
      CC(3)=-AC(3)-BC(3)                                                NTSTIF.171
      CALL CONCNE(CMP(1,NINT),F,OTU,SA2,AC,BC,CC,SY,NINDIN),SL)         NTSTIF.172
C                                                                       NTSTIF.173
      IF(JUMP .EQ. 0( NIND(N)=0                                         NTSTIF.174
C     CHECK IF IT IS YIELD                                              NTSTIF.175
      IF(NIND(N) .NE. 0) GO TO 323                                      NTSTIF.176
      WRITE(41) (SS(I),I=1,80)                                          NTSTIF.177
      GO TO 302                                                         NTSTIF.178
  323 CONTINUE                                                          NTSTIF.179
C                                                                       NTSTIF.180
C     FORM YIELD STIFFNESS ASA-GLOBAL                                   NTSTIF.181
      DO 309 I=1,2                                                      NTSTIF.182
      NODE=IX(I,N)                                                      NTSTIF.183
      XX(I)=X(NODE)                                                     NTSTIF.184
      YY(I)=Y(NODE)                                                     NTSTIF.185
  309 CONTINUE                                                          NTSTIF.186
       CALL CONCTS(XX,YY,PARACO,COPROF,IX(1,N),IBC(1,N),C(1,N(,SLV,SY,  NTSTIF.187
     1             NIND(N()                                             NTSTIF.188
C                                                                       NTSTIF.189
C     FORM TANGENT STIFFNESS BY SUBTRACTING ASA FROM AEN                NTSTIF.190
      CALL SUBTRC(AEN,NEQ)                                              NTSTIF.191
      GO TO 302                                                         NTSTIF.192
  403 CONTINUE                                                          NTSTIF.193
C                                                                       NTSTIF.194
C     TYPE 3,FRICTION ELEMENT                                           NTSTIF.195
C     TYPE 4,EXPANSION JOINT                                            NTSTIF.196
C                                                                       NTSTIF.197
C     READ ELEMENT (NFORMATION FROM TAPE 1                              NTSTIF.198
      READ(1) (SS(I),(=1,138(                                           NTSTIF.199
C     SET UP D(SPLACEMENT(GLOBAL)-STRESS(LOCAL) MATRIX-SA4(8,8)         NTSTIF.200
      KK=66                                                             NTSTIF.201
      DO 310 (=1,8                                                      NTSTIF.202
      KI=KK+8*I                                                         NTSTIF.203
      DO 311 J=1,8                                                      NTSTIF.204
      JI=KI+J                                                           NTSTIF.205
  311 SA4(J,()=SS(JI)                                                   NTSTIF.206
  310 CONTINUE                                                          NTSTIF.207
      DO 343 I=1,8                                                      NTSTIF.208
      DO 343 J=1,8                                                      NTSTIF.209
      SE(I,J)=SA4(I,J)                                                  NTSTIF.210
  343 CONTINUE                                                          NTSTIF.211
C                                                                       NTSTIF.212
C     LOCATION OF MASS                                                  NTSTIF.213
      DO 312 (=1,8                                                      NTSTIF.214
  312 LM(()=(SS(2*I)                                                    NTSTIF.215
C                                                                       NTSTIF.216
C     FIND INCREMENTAL NODAL DISPLACEMENT,AND NODAL FORCES              NTSTIF.217
      DO 313 I=1,8                                                      NTSTIF.218
      II=(I+1(/2                                                        NTSTIF.219
      JJ=LM(I)                                                          NTSTIF.220
      IF(JJ .NE. 0) GO TO 408                                           NTSTIF.221
      UE(I)=0.0                                                         NTSTIF.222
      DTU(()=0.0                                                        NTSTIF.223
      GO TO 409                                                         NTSTIF.224
  408 CONTINUE                                                          NTSTIF.225
      DTU(I)=DU(JJ)                                                     NTSTIF.226
      IF(MOD(I,2( .EQ. 0) GO TO 409                                     NTSTIF.227
      UE(II)=U(JJ)                                                      NTSTIF.228
  409 F(I)=SIG(I,N)                                                     NTSTIF.229
      VE(I)=V(JJ)                                                       NTSTIF.230
  313 CONTINUE                                                          NTSTIF.231
      IF(NTYPE .EQ. 4( GO TO 410                                        NTSTIF.232
C     FRICTION ELEMENT                                                  NTSTIF.233
C                                                                       NTSTIF.234
      CALL PFRICT(PARAFR(1,MATYPE),SA4,DTU,F,C(1,N),NINDIN))            NTSTIF.235
      GO TO 411                                                         NTSTIF.236
  410 CONTINUE                                                          NTSTIF.237
      CALL PEXPAN(PARAFR(1,MATYPE),PARAEX(1,MATYPE(.SA4,UE,DTU,VE,F,    NTSTIF.238
     1            C(1,N),NINDIN)) ,                                     NTSTIF.239
  411 CONTINUE                                                          NTSTIF.240
C                                                                       NTSTIF.241
C     CHECK IF IT IS YIELD                                              NTSTIF.242
      IF(NINDIN) .NE. 0) GO TO 324                                      NTSTIF.243
      WRITE(41) (SS(I),I=1,138)                                         NTSTIF.244
      GO TO 302                                                         NTSTIF.245
  324 CONTINUE                                                          NTSTIF.246
      DO 314 I=1,4                                                      NTSTIF.247
      NODE=IX(I,N)                                                      NTSTIF.248
      XX(I)=X(NODE)                                                     NTSTIF.249
      YY(I)=Y(NODE)                                                     NTSTIF.250
  314 CONTINUE                                                          NTSTIF.251
C                                                                       NTSTIF.252
C     FORM TANGENT STIFFNESS-ASA(GLOBAL)                                NTSTIF.253
      CALL FRICTSIXX,YY,C(1,N))                                         NTSTIF.254
      CALL SUBTRC(AEN,NEQ)                                              NTSTIF.255
      GO TO 302                                                         NTSTIF.256
C                                                                       NTSTIF.257
  405 CONTINUE                                                          NTSTIF.258
C     TYPE 5,BOUNDARY ELEMENT                                           NTSTIF.259
      READ(1) (SS(I),I=1,8)                                             NTSTIF.260
C                                                                       NTSTIF.261
C     LOCATION OF MASS                                                  NTSTIF.262
      DO 315 I=1,2                                                      NTSTIF.263
  315 LM(I)=ISS(2*I)                                                    NTSTIF.264
      DO 360 I=3,8                                                      NTSTIF.265
      LM(I)=0                                                           NTSTIF.266
  360 CONTINUE                                                          NTSTIF.267
      KK=2                                                              NTSTIF.268
      DO 344 I=1,2                                                      NTSTIF.269
      KI=KK+2*I                                                         NTSTIF.270
      DO 345 J=1,2                                                      NTSTIF.271
      JI=KI+J                                                           NTSTIF.272
  345 SE(J,I)=SSIJI)                                                    NTSTIF.273
  344 CONTINUE                                                          NTSTIF.274
      DO 316 I=1,8                                                      NTSTIF.275
      JJ=LM(I)                                                          NTSTIF.276
      IF(JJ .NE. 0) GO TO 412                                           NTSTIF.277
      DTU(()=0.0                                                        NTSTIF.278
      GO TO 413                                                         NTSTIF.279
  412 CONTINUE                                                          NTSTIF.280
      OTU(()=OU(JJ)                                                     NTSTIF.281
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  413 F(I)=S)G(),N)-DS)G(),N)                                          NTSTIF.282
  316 CONTINUE                                                         NTSTIF.283
      CALL PBOUND(PARA80(1,MATYPE),OTU,F,C(1,N),NINO(N))               NTSTIF.284
      )F(NINO(N) .NE. 0) GO TO 325                                     NTSTIF.285
      WR)TE(41) (SS()),I=I,8)                                          NTSTIF.286
      GO TO 302                                                        NTSTIF.287
  325 CONTINUE                                                         NTSTIF.288
      CALL BOUNOS(C(1,N))                                              NTSTIF.289
      CALL SUBTRC(AEN,NEQ)                                             NTSTIF.290
  302 CONTINUE                                                         NTSTIF.291
C     SET NEW ELASTIC STIFFNESS AFTER STATIC ANALYSIS                  NTSTIF.292
      IF(JUMP .NE. 0) GO TO 414                                        NTSTIF.293
      )F(NY)ELO .NE. 2) GO TO 414                                      NTSTIF.294
      WRITE(3) ((AEN(I,J),I=1,NEQ),J=1,MBANO)                          NTSTIF.295
  414 CONTINUE                                                         NTSTIF.296
      RETURN                                                           NTSTIF.297
      END                                                              NTSTIF.298
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      SUBROUTINE SUBTRC(AEN,NEQ)                                       SUBTRC.2
C                                                                      SUBTRC.3
C     ***************************************************************SUBTRC.4
C     FORN TANGENT STIFFNESS BY SUBTRACTING THE YIELD STIFFNESS ASA FROMSUBTRC.5
C     TOTAL ELASTIC STIFFNESS-AEN                                      SUBTRC.6
C     ***************************************************************SUBTRC.7
      OIMENSION AEN(NEQ,1)                                             SUBTRC.8
      COMMON/ER/LM(8),ASA(8,8)                                         SUBTRC.9
      00 301 I=1,8                                                     SUBTRC.10
      I)=LN())                                                         SUBTRC.11
      )F(I) .EO. 0) GO TO 301                                          SUBTRC.12
      00 302 J=I,8                                                     SUBTRC.13
      JJ=LN(J)-II+1                                                    SUBTRC.14
      IF(JJ .LT. 1) GO TO 301                                          SUBTRC.15
  302 AEN(II,JJ)=AEN(II,JJ)-ASA(I,J)                                   SUBTRC.16
  301 CONTINUE                                                         SUBTRC.17
      RETURN                                                           SUBTRC.18
      END                                                              SUBTRC.19
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      SUBROUTINE SO)LNE(PARASO,K2S,TEPS,OEPS,PEPS,OSIG,SIG,PSIG,       SOILNE.2
     1                  SY,GS,SIGNST,N)ND,NPASS)                       SOILNE.3
C                                                                      SOILNE.4
C     ***************************************************************SOILNE.5
C     CHECK THE SO)L )S Y)ELO,ANO FORM Y)ELO STIFFNESS NATRIX--         SOILNE.6
C     SY(LOCAL)--BY CALING SUBROUTINE PSOIL                            SOILNE.7
C     ***************************************************************SOILNE.8
C                                                                      SOILNE.9
      OINENSION PARASO(8),K2S(20),TEPS(3),OEPS(3),PEPS(3),OSIG(8I,     SOILNE.10
     1          SIG(8),PS)G(4),SY(6,6),PSSIG(3)                        SOILNE.11
      CONNON/TINE/JUMP,T,OT,MPRTN,MTAPE,KPRINT                         SOILNE.12
      COMMON/MATER/NUMATS,NUMATC,NUNATF,NUMATE,NUMAT8,NUMGE,NINTCV,THICKSOILNE.13
     1,NPLAN                                                          SOILNE.14
      OIMENSION SIGNSN(350)                                            SOILNE.15
      COMMON/NELEN/N                                                   SOILNE.16
      REAL K2S                                                         SOILNE.17
C                                                                      SOILNE.18
C     SET UP LINEAR INOICATOR,ANO BAS)C PARAMETERS OF SOIL             SOILNE.19
      NIND=0                                                           SOILNE.20
      NPASS=0                                                          SOILNE.21
      G1=PARASO(1)                                                     SOILNE.22
      G2=PARASO(2)                                                     SOILNE.23
      ANU=PARASO(3)                                                    SOILNE.24
      C=PARASO(4)                                                      SOILNE.25
      PHI=PARASO(5)                                                    SOILNE.26
      PHI=PHI)/57.2978                                                 SOILNE.27
      GAMMAY=PARASO(6)                                                 SOILNE.28
C                                                                      SOILNE.29
C     DETERMIME WHICH STRESS-STRAIN LAW IS USED                        SOILNE.30
C     LINEAR CASE                                                      SOILNE.31
      IF(G1 .EQ. G2) RETURN                                            SOILNE.32
C                                                                      SOILNE.33
C     BILINEAR CASE WITH SHEAR STRAIN CONTROL--FOR ONE DIMENSIONAL SHEARSOILNE.34
C     BEAN CASE ONLY                                                   SOILNE.35
      IF(GANNAY .NE. 0.0) GO TO 408                                    SOILNE.36
      IF(JUMP .NE. 0) GO TO 403                                        SOILNE.37
C                                                                      SOILNE.38
C     SAVE STATIC MEAN STRESS FOR DE7ECTING ACTIVE OR PASSIVE FAILURE, SOILNE.39
C     CALCULATE NEW STIFFNESS AT THE END OF STATIC ANALYSIS            SOILNE.40
      IF(NPLAN .EO. 0) GO TO 402                                       SOILNE.41
C                                                                      SOILNE.42
C     PLANE STRESS,MEAN SQ. STRESS                                     SOILNE.43
      SIGMST=(SIG(1)+SIG(2))/2.0                                       SOILNE.44
      SIGMSN(N)=SIGNST                                                 SOILNE.45
      SIGMST=ABS(SIGMST)                                               SOILNE.46
      SIGME=SQRT(SIGMST)                                               SOILNE.47
      GO TO 403                                                        SOILNE.48
C                                                                      SOILNE.49
C     PLAIN STRAIN                                                     SOILNE.50
  402 CONTINUE                                                         SOILNE.51
      SIGME=(SIG(1)+SIG(2II*(1.0+ANU)/3.0                              SOILNE.52
      SIGNST=(SIG(1)+SIG(2))/2.0                                       SOILNE.53
      SIGMSN(N)=SIGMST                                                 SOILNE.54
      SIGME=ABS(SIGME)                                                 SOILNE.55
      SIGME=SQRT(SIGME)                                                SOILNE.56
C                                                                      SOILNE.57
  403 CONTINUE                                                         SOILNE.58
C                                                                      SOILNE.59
C     BILINEAR CASE WITH COLOMB-MOHR,WITHOUT STRAIN-HARDENING          SOILNE.60
      IF(K2S(1) .EQ. 0.0) GO TO 407                                    SOILNE.61
      )F(JUMP .NE. 0) GO TO 451                                        SOILNE.62
C     ***************************************************************SOILNE.63
C     TRILINEAR CASE WITH CURVE FROM EERC-70-10,NO HARDENING           SOILNE.64
C     ***************************************************************SOILNE.65
      GAMMAX=PEPS(3)                                                   SOILNE.66
C                                                                      SOILNE.67
C     CHECK WITH SHEAR MODULUS CURVE K2S FOR COFF. K2                  SOILNE.68
      IF(GAMMAX .LT. K2S(2)) RETURN                                    SOILNE.69
      00 301 I=1,10                                                    SOILNE.70
      IF(GAMMAX .GE. K2S(2*I) .AND. GAMMAX .LT. K2S(2*I+2))  GO TO 405 SOILNE.71
  301 CONTINUE                                                         SOILNE.72
  405 CONTINUE                                                         SOILNE.73
C                                                                      SOILNE.74
C     CHECK IF )T IS YIELD                                             SOILNE.75
      GS=G1                                                            SOILNE.76
      CALL PSOIL(OSIG,SIG,PSIG,SY,GS,ANU,C,PHI,NIND)                   SOILNE.77
      IF(NINO .EQ. 1) GO TO 406                                        SOILNE.78
      )F(GAMMAX .NE. K2S(2*I)) GO TO 409                               SOILNE.79
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      AK2=K2S(2*I-1)                                                    SOILNE.79
      GO TO 410                                                         SOILNE.80
  409 AK2=(K2S(2*I-1)+K2S(2*I+1))/2.0                                   SOILNE.81
  410 CONTINUE                                                          SOILNE.82
C                                                                       SOILNE.83
C     MODIFIED ELASTIC STIFFNESS IN KSI                                 SOILNE.84
      GS=AK2*2.638*SIGNE                                                SOILNE.85
      GS=G1-GS                                                          SOILNE.86
      NIND=2                                                            SOILNE.87
      RETURN                                                            SOILNE.88
  451 CONTINUE                                                          SOILNE.89
      CALL PSOIL(OSIG,SIG,PSIG,SY,GS,ANU,C,PHI,NIND)                    SOILNE.90
      IF(NIND .EQ. 1) GO TO 406                                         SOILNE.91
      RETURN                                                            SOILNE.92
  406 CONTINUE                                                          SOILNE.93
C                                                                       SOILNE.94
C     CHECK IF IT IS ACTIVE OR PASSIVE FAILURE,NPASS=1 ACTIVE FAILURE,  SOILNE.95
C     NPASS=2 PASSIVE FAILURE                                           SOILNE.96
C     NPASS=0 EALSTIC                                                   SOILNE.97
      IF(NIND .EQ. 0) RETURN                                            SOILNE.98
      SIGM=(SIG(1)+SIG(2))/2.0                                          SOILNE.99
      IF(SIGN .GE. SIGMSN(N)) NPASS=1                                   SOILNE.100
      IF(SIGM .LT. SIGMSN(N)) NPASS=2                                   SOILNE.101
      RETURN                                                            SOILNE.102
C     ******************************************                        SOILNE.103
C     BILINEAR WITH COULOMB-MOHR NO HARDENING                           SOILNE.104
C     ******************************************                        SOILNE.105
  407 CONTINUE                                                          SOILNE.106
      GS=G1                                                             SOILNE.107
      CALL PSOIL(OSIG,SIG,PSIG,SY,GS,ANU,C,PHI,NIND)                    SOILNE.108
      IF( NIND .EQ. 1) GO TO 411                                        SOILNE.109
      RETURN                                                            SOILNE.110
  411 CONTINUE                                                          SOILNE.111
C     CHECK IF IT IS ACTIVE OR PASSIVE YIELD                            SOILNE.112
C                                                                       SOILNE.113
      SIGM=(SIG(1)+SIG(2))/2.0                                          SOILNE.114
      IF(SIGN .GE. SIGNSN(N)) NPASS=1                                   SOILNE.115
      IF(SIGN .LT. SIGNSN(N)) NPASS=2                                   SOILNE.116
      RETURN                                                            SOILNE.117
C     ******************************************                        SOILNE.118
C     SHEAR STRAIN CONTROL-SHEAR BEAM ONLY                              SOILNE.119
C     ******************************************                        SOILNE.120
  408 CONTINUE                                                          SOILNE.121
      GAMMAX=TEPS(3)                                                    SOILNE.122
C                                                                       SOILNE.123
C     CALCULATE UPPER LIMIT AND LOWER LIMIT LINES                       SOILNE.124
      TAU=GAMMAX*(G1-G2)+G2*GAMMAX                                      SOILNE.125
      TAL=GAMMAY*(G2-G1)+G2*GAMMAX                                      SOILNE.126
C     ELASTIC CASE                                                      SOILNE.127
      IF(SIG(3) .LT. TAU .AND. SIG(3) .GT. TAL) RETURN                  SOILNE.128
C                                                                       SOILNE.129
C     CHECK LOADING OR UNLOADING WHEN YIELDING                          SOILNE.130
      PSSIG(3)=SIG(3)+DEPS(3)*G1                                        SOILNE.131
C     UNLOADING FROM YIELDING,ELASTIC CASE                              SOILNE.132
      IF(PSSIG(3) .LT. TAU .AND. PSSIG(3) .GT. TAL) RETURN              SOILNE.133
C                                                                       SOILNE.134
C     PLANE STRAIN FOR SHEAR BEAM ANALYSIS                              SOILNE.135
      IF(G2 .EQ. 0.0) G2=G1/100000000.0                                 SOILNE.136
      GP=G1-G2                                                          SOILNE.137
      DO 452 I=1,6                                                      SOILNE.138
      DO 452 J=1,6                                                      SOILNE.139
  452 SY(I,J)=0.0                                                       SOILNE.140
      SY(1,1)=2.0*(1.0-ANU)*GP/(1.0-2.0*ANU)                            SOILNE.141
      SY(1,2)=2.0*ANU*GP/(1.0-2.0*ANU)                                  SOILNE.142
      SY(3,3)=GP                                                        SOILNE.143
      SY(2,2)=SY(1,1)                                                   SOILNE.144
      SY(2,1)=SY(1,2)                                                   SOILNE.145
      NIND=1                                                            SOILNE.146
      RETURN                                                            SOILNE.147
      END                                                               SOILNE.148
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      SUBROUTINE PSOIL(OSIG,SIG,PSIG,SY,GS,ANU,C,PHI,NIND)              PSOIL.2
C                                                                       PSOIL.3
C     ******************************************************************PSOIL.4
C     FORM PLASTIC STRESS-STRAIN RELATIONSHIP-SY(LOCAL)                 PSOIL.5
C     ******************************************************************PSOIL.6
C                                                                       PSOIL.7
      DIMENSION PARAS0(8),K2S(20),TEPS(3),DEPS(3),PEPS(3)               PSOIL.8
      DIMENSION DSIG(8),SIG(8),PSIG(4),SY(6,6),DF(3),QP(3)              PSOIL.9
C                                                                       PSOIL.10
C     CHECK IF IT IS  YIELD FOR BILINEAR CASE                           PSOIL.11
      T3=2.0*C*COS(PHI)/1000.0                                          PSOIL.12
      T1=(1.0+SIN(PHI))*PSIG(1)                                         PSOIL.13
      T2=(1.0-SIN(PHI))*PSIG(2)                                         PSOIL.14
      F=T1-T2-T3                                                        PSOIL.15
      IF(F .LT. 0.0) RETURN                                             PSOIL.16
C                                                                       PSOIL.17
C     CHECK IF IT IS LOADING OR UNLOADING                               PSOIL.18
      T=(SIG(1)+SIG(2))/2.0                                             PSOIL.19
      T2=T**2                                                           PSOIL.20
      R=T2+SIG(3)**2                                                    PSOIL.21
      R=SQRT(R)                                                         PSOIL.22
      DF(1)=T/R/2.0+0.5*SIN(PHI)                                        PSOIL.23
      DF(2)=DF(1)                                                       PSOIL.24
      DF(3)=SIG(3)/R                                                    PSOIL.25
      DL=DF(1)*DSIG(1)+DF(2)*DSIG(2)+DF(3)*DSIG(3)                      PSOIL.26
      IF(DL .LT. 1.0E-10) RETURN                                        PSOIL.27
      NIND=1                                                            PSOIL.28
      B=0.5*SIN(PHI)                                                    PSOIL.29
      B1=2.0*B*B/(1.0-2.0*ANU)                                          PSOIL.30
      B2=SIG(3)**2/R**2                                                 PSOIL.31
      AC=B1+0.5+1.5*B2                                                  PSOIL.32
C                                                                       PSOIL.33
C     FORM COMPONENTS OF PLASTIC STRESS-STRAIN LAW-QP(3)                PSOIL.34
      TE=(SIG(1)-SIG(2))/4.0/R                                          PSOIL.35
      QP(1)=B/(1.0-2.0*ANU)+TE                                          PSOIL.36
      QP(2)=B/(1.0-2.0*ANU)-TE                                          PSOIL.37
      QP(3)=SIG(3)/R                                                    PSOIL.38
      EA=GS*2.0/AC                                                      PSOIL.39
C                                                                       PSOIL.40
C     FORM PLASTIC MODULUS-SY(3,3)                                      PSOIL.41
      DO 302 I=1,3                                                      PSOIL.42
      DO 302 J=1,3                                                      PSOIL.43
      SY(I,J)=QP(I)*QP(J)                                               PSOIL.44
      SY(I,J)=EA*SY(I,J)                                                PSOIL.45
  302 CONTINUE                                                          PSOIL.46
      RETURN                                                            PSOIL.47
      END                                                               PSOIL.48
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      SUBROUTINE CONCNE(CMP,F,OTU,S,A,B,C,SY,NIND,SL)                   CONCNE.2
C                                                                       CONCNE.3
C     ****************************************************************CONCNE.4
C     CHECK IF THE ELEMENT IS YIELO,AND FORM YIELO STIFFNESS SY(LOCAL)  CONCNE.5
C     BY CALLING PCOL                                                   CONCNE.6
C     ****************************************************************CONCNE.7
C                                                                       CONCNE.8
      DIMENSION F(6),OF(6),OTU(6),S(6,6),FN(2),FP(2),FV(2),             CONCNE.9
     1          FPN(2),FMN(2),A(3),B(3),C(3),CMP(9),PHI(2)              CONCNE.10
      DIMENSION SY(6,6),SL(6,6)                                         CONCNE.11
      COMMON/TIME/JUMP,T,OT,MPRTM,MTAPE,KPRINT                          CONCNE.12
C                                                                       CONCNE.13
C     SET UP LINEAR INDICATOR NIND=0 ELASTIC,NIND=1 PLASTIC             CONCNE.14
      NIND=0                                                            CONCNE.15
C                                                                       CONCNE.16
C     CALCULATE APPARENT ELASTIC INCREMENTAL END FORCES-OF(6)           CONCNE.17
      DO 301 I=1,6                                                      CONCNE.18
      XA=0.0                                                            CONCNE.19
      DO 302 J=1,6                                                      CONCNE.20
      XA=XA+S(I,J)*OTU(J)                                               CONCNE.21
  302 CONTINUE                                                          CONCNE.22
      OF(I)=XA                                                          CONCNE.23
  301 CONTINUE                                                          CONCNE.24
C     CHECK YIELOING CONDITION                                          CONCNE.25
C                                                                       CONCNE.26
      FP(1)=F(1)+OF(1)                                                  CONCNE.27
      FV(1)=F(2)+OF(2)                                                  CONCNE.28
      FN(1)=F(3)+OF(3)                                                  CONCNE.29
      FP(2)=F(4)+OF(4)                                                  CONCNE.30
      FV(2)=F(5)+OF(5)                                                  CONCNE.31
      FN(2)=F(6)+OF(6)                                                  CONCNE.32
C                                                                       CONCNE.33
C     TENSIONAL YIELO AT BOTH ENDS                                      CONCNE.34
      IF(FP(1) .LT. 0.0 .AND. FP(2) .GT. 0.0) GO TO 405                 CONCNE.35
C                                                                       CONCNE.36
C     NORMALIZE THE END FORCES                                          CONCNE.37
      FPN(1)=FP(1)/CMP(5)                                               CONCNE.38
      FMN(1)=FN(1)/CMP(6)                                               CONCNE.39
      FPN(2)=FP(2)/CMP(5)                                               CONCNE.40
      FMN(2)=FN(2)/CMP(6)                                               CONCNE.41
      FMN(1)=ABS(FMN(1))                                                CONCNE.42
      FMN(2)=ABS(FMN(2))                                                CONCNE.43
      FPN(2)=ABS(FPN(2))                                                CONCNE.44
C                                                                       CONCNE.45
C     DETERMINE THE ECCENTRICITY IN INCHES                              CONCNE.46
      IF(FP(1) .EQ. 0.0) GO TO 411                                      CONCNE.47
      EC1=FN(1)/FP(1)                                                   CONCNE.48
      EC1=ABS(EC1)                                                      CONCNE.49
      GO TO 413                                                         CONCNE.50
  411 EC1=100.0                                                         CONCNE.51
  413 CONTINUE                                                          CONCNE.52
      IF(FP(2) .EQ. 0.0) GO TO 412                                      CONCNE.53
      EC2=FN(2)/FP(2)                                                   CONCNE.54
      EC2=ABS(EC2)                                                      CONCNE.55
      GO TO 414                                                         CONCNE.56
  412 EC2=100.0                                                         CONCNE.57
  414 CONTINUE                                                          CONCNE.58
C                                                                       CONCNE.59
C     FORM YIELO FCTN AT I END                                          CONCNE.60
      JJ=0                                                              CONCNE.61
      DO 303 I=1,3                                                      CONCNE.62
      II=I-1                                                            CONCNE.63
      JJ=JJ+1                                                           CONCNE.64
      IF(EC1 .LE. CMP(3*II+1)) GO TO 401                                CONCNE.65
  303 CONTINUE                                                          CONCNE.66
  401 CONTINUE                                                          CONCNE.67
      AM1=A(JJ)                                                         CONCNE.68
      BM1=B(JJ)                                                         CONCNE.69
      CM1=C(JJ)                                                         CONCNE.70
      PHI(1)=1.0+CM1/(AM1*FPN(1)+BM1*FMN(1))                            CONCNE.71
      SIGN=FP(1)*FP(2)                                                  CONCNE.72
C     CASE OF ONE END TENSION,ONE END COMPRESSION TREAT AS ELASTIC      CONCNE.73
      IF(SIGN .GT. 0.0) PHI(1)=-0.1                                     CONCNE.74
C                                                                       CONCNE.75
C     FORM YIELO FCTN AT J END                                          CONCNE.76
      JJ=0                                                              CONCNE.77
      DO 304 I=1,3                                                      CONCNE.78
      II=I-1                                                            CONCNE.79
      JJ=JJ+1                                                           CONCNE.80
      IF(EC2 .LE. CMP(3*II+1)) GO TO 402                                CONCNE.81
  304 CONTINUE                                                          CONCNE.82
  402 CONTINUE                                                          CONCNE.83
      AM2=A(JJ)                                                         CONCNE.84
      BM2=B(JJ)                                                         CONCNE.85
      CM2=C(JJ)                                                         CONCNE.86
      PHI(2)=1.0+CM2/(AM2*FPN(2)+BM2*FMN(2))                            CONCNE.87
C     CASE OF ONE END TENSION,ONE END COMPRESSION TREAT AS ELASTIC      CONCNE.88
      IF(SIGN .GT. 0.0) PHI(2)=-0.1                                     CONCNE.89
      AM1=-AM1/CM1                                                      CONCNE.90
      BM1=-BM1/CM1                                                      CONCNE.91
      AM2=-AM2/CM2                                                      CONCNE.92
      BM2=-BM2/CM2                                                      CONCNE.93
C                                                                       CONCNE.94
C     BOTH ENDS ELASTIC                                                 CONCNE.95
      IF(PHI(1) .LT. 0.0 .AND. PHI(2) .LT. 0.0) GO TO 407               CONCNE.96
C                                                                       CONCNE.97
C     I END YIELO                                                       CONCNE.98
      IF(PHI(1) .GE. 0.0 .AND. PHI(2) .LT. 0.0) GO TO 403               CONCNE.99
C                                                                       CONCNE.100
C     J END YIELO                                                       CONCNE.101
      IF(PHI(1) .LT. 0.0 .AND. PHI(2) .GE. 0.0) GO TO 404               CONCNE.102
C                                                                       CONCNE.103
C     BOTH ENDS YIELO                                                   CONCNE.104
      IF(PHI(1) .GE. 0.0 .AND. PHI(2) .GE. 0.0) GO TO 406               CONCNE.105
C                                                                       CONCNE.106
C     ELASTIC-PLASTIC  BEAM WITH I END YIELO                            CONCNE.107
  403 CONTINUE                                                          CONCNE.108
      NIND=1                                                            CONCNE.109
      CALL PCOL(1,AM1,BM1,AM2,BM2,S,SY,SL)                              CONCNE.110
      GO TO 407                                                         CONCNE.111
C                                                                       CONCNE.112
C     ELASTIC-PLASTIC BEAM WITH J END YIELO                             CONCNE.113
  404 CONTINUE                                                          CONCNE.114
      NIND=1                                                            CONCNE.115
      CALL PCOL(2,AM1,BM1,AM2,BM2,S,SY,SL)                              CONCNE.116
      GO TO 407                                                         CONCNE.117
  405 CONTINUE                                                          CONCNE.118
C     BOTH ENDS YIELO IN TENSION                                        CONCNE.119
      NIND=1                                                            CONCNE.120
      AM1=-CMP(5)                                                       CONCNE.121
      AM2=-CMP(5)                                                       CONCNE.122
      BM1=0.0                                                           CONCNE.123
      BM2=0.0                                                           CONCNE.124
  406 CONTINUE                                                          CONCNE.125
C     ELASTIC-PLASTIC BEAM WITH BOTH ENDS YIELO                         CONCNE.126
      CALL PCOL(3,AM1,BM1,AM2,BM2,S,SY,SL)                              CONCNE.127
  407 CONTINUE                                                          CONCNE.128
      RETURN                                                            CONCNE.129
      END                                                               CONCNE.130
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      SUBROUTINE PCOL(NODE,AM1,BM1,AM2,BM2,S,SY,SL(                     PCOL.2
C                                                                       PCOL.3
C     ********************************************************************PCOL.4
C     CALCULATE THE STIFFNESS-SY(LOCAL(                                 PCOL.5
C     ********************************************************************PCOL.6
C                                                                       PCOL.7
      DIMENSION S(6,6(,SY(6,6(,YSI6,2(,BB(2,2(,AAI2,2(,BAI6,2(,BSI2,6(  PCOL.8
      DIMENSION SL(6,6(                                                 PCOL.9
      COMMON/TIME/JUMP,T,DT,MPRTN,NTAPE,KPRINT                          PCOL.10
C                                                                       PCOL.11
C     INITILIZATION                                                     PCOL.12
      DO 301 I=1,6                                                      PCOL.13
      DO 301 J=1,2                                                      PCOL.14
      YS((,J)=0.0                                                       PCOL.15
  301 CONTINUE                                                          PCOL.16
      DO 311 I=1,2                                                      PCOL.17
      DO 311 J=1,2                                                      PCOL.18
      AA((,J(=0.0                                                       PCOL.19
  311 CONTINUE                                                          PCOL.20
C     SET UP LOCAL STRESS-STRAIN RELATIONSHIP                           PCOL.21
      DO 312 I=1,6                                                      PCOL.22
      DO 312 J=1,6                                                      PCOL.23
      S(I,J(=SL(I,J(                                                    PCOL.24
  312 CONTINUE                                                          PCOL.25
C                                                                       PCOL.26
C     NODE=1 I END YIELD,NC=1                                           PCOL.27
C     NODE=2,J END YIELD,NC=1                                           PCOL.28
C     NODE=3,BOTH END YIELD,NC=2                                        PCOL.29
      NC=1                                                              PCOL.30
      IF(NODE .EQ. 3( GO TO 402                                         PCOL.31
      IF(NODE .EQ. 2( GO TO 401                                         PCOL.32
C                                                                       PCOL.33
C     I END YIELD                                                       PCOL.34
      YS(1,1(=AM1                                                       PCOL.35
      YS(3,1(=BM1                                                       PCOL.36
      GO TO 403                                                         PCOL.37
  401 CONTINUE                                                          PCOL.38
C                                                                       PCOL.39
C     J END YIELD                                                       PCOL.40
      YS(4,1(=AM2                                                       PCOL.41
      YS(6,1(=BM2                                                       PCOL.42
      GO TO 403                                                         PCOL.43
  402 CONTINUE                                                          PCOL.44
C                                                                       PCOL.45
C     BOTH END YIELD                                                    PCOL.46
      NC=2                                                              PCOL.47
      YSI1,1(=AM1                                                       PCOL.48
      YSI3,1(=BM1                                                       PCOL.49
      YS(4,2(=AM2                                                       PCOL.50
      YS(6,2(=BM2                                                       PCOL.51
  403 CONTINUE                                                          PCOL.52
      DO 303 K=1,NC                                                     PCOL.53
      DO 303 I=1,6                                                      PCOL.54
      XA=0.0                                                            PCOL.55
      DO 304 J=1,6                                                      PCOL.56
      AA=AA+YS(J,K(*S(J,I(                                              PCOL.57
  304 CONTINUE                                                          PCOL.58
      BS(K,I(=XA                                                        PCOL.59
  303 CONTINUE                                                          PCOL.60
      DO 305 I=1,NC                                                     PCOL.61
      DO 305 J=1,NC                                                     PCOL.62
      XA=0.0                                                            PCOL.63
      DO 306 K=1,6                                                      PCOL.64
      XA=XA+BS(J,K(*YS(K,I(                                             PCOL.65
  306 CONTINUE                                                          PCOL.66
      BB(J,I(=XA                                                        PCOL.67
  305 CONTINUE                                                          PCOL.68
      OET=BB(1,1(                                                       PCOL.69
      IF(NODE .NE. 3( GO TO 404                                         PCOL.70
      OET=BB(1,1(*BB(2,2(-BB(1,2(*BBI2,1(                               PCOL.71
  404 CONTINUE                                                          PCOL.72
      (F(OET .LT. 1.0E-30( GO TO 405                                    PCOL.73
      AA(1,1)=1.0/DET                                                   PCOL.74
      IF(NODE .NE. 3( GO TO 405                                         PCOL.75
      AA(1,I)=BBI2,2(/OET                                               PCOL.76
      AAI1,2(=-BB(1,2(/DET                                              PCOL.77
      AA(2,1(=AA(1,2(                                                   PCOL.78
      AA(2,2(=BB(1,1(/OET                                               PCOL.79
  405 CONTINUE                                                          PCOL.80
      DO 307 I=1,6                                                      PCOL.81
      DO 307 J=1,NC                                                     PCOL.82
      XA=0.0                                                            PCOL.83
      DO 308 K=1,NC                                                     PCOL.84
      XA=XA+BS(K,I(*AA(K,J(                                             PCOL.85
  308 CONTINUE                                                          PCOL.86
      BA((,J)=XA                                                        PCOL.87
  307 CONTINUE                                                          PCOL.88
      DO 309 I=1,6                                                      PCOL.89
      DO 309 J=1,6                                                      PCOL.90
      XA=0.0                                                            PCOL.91
      DO 310 K=1,NC                                                     PCOL.92
      XA=XA+BA((,K(*BS(K,J(                                             PCOL.93
  310 CONTINUE                                                          PCOL.94
      SY(I,J(=XA                                                        PCOL.95
  309 CONTINUE                                                          PCOL.96
      DO 313 I=1,6                                                      PCOL.97
      IF(SY(I,I( .LE. D.0( SYII,I(=0.9*SLII,I(                          PCOL.98
      DO 313 J=1,6                                                      PCOL.99
      IF(SY(I,J( .GT. 0.9*SLII,J(( SYII,JI=D.9*SL(I,J(                  PCOL.100
  313 CONTINUE                                                          PCOL.101
      RETURN                                                            PCOL.102
      END                                                               PCOL.103
```

```
      SUBROUTINE PFRICT(PARAFR,SA,DTU,P,C,NINO)  .                      PRICT7.2
C                                                                       PRICTT.3
C     ********************************************************************PRICTT.4
C     CHECK IF THE FRICTIONAL ELEMENT IS YIELO,AND THEN FORM THE YIELD  PRICTT.5
C     STRESS-STRAIN CONSTANTS--CYI4(=CI4(                               PRICTT.6
C     ********************************************************************PRICTT.7
C                                                                       PRICTT.8
      DIMENSION PARAFRI4(,SAI8,8(,DTUI8(,FI8(,CI4I,DFI8I                PRICTT.9
      COMMON/TIME/JUMP,T,DT,MPRTN,NTAPE,KPRINT                          PRICTT.10
C                                                                       PRICTT.11
C     SET LINEAR INDICATOR--NINO                                        PRICTT.12
      NINO=0                                                            PRICTT.13
      AKS=PARAFRI1(                                                     PRICTT.14
      AKN=PARAFRI2I                                                     PRICTT.15
C                                                                       PRICTT.16
C     CALCULATE APPARENT ELATIIC INCREMENTAL END FORCES-DFI8(           PRICTT.17
      DO 301 I=1,8                                                      PRICTT.18
      XA=D.0                                                            PRICTT.19
      DO 302 J=1,8                                                      PRICTT.20
      XA=XA+SAII,J(*DTUIJ(                                              PRICTT.21
  302 CONTINUE                                                          PRICTT.22
      DFII(=XA                                                          PRICTT.23
  301 CONTINUE                                                          PRICT7.24
C                                                                       PRICTT.25
C     AVERAGE APPARENT STRESS AT CENTER OF ELEMENT                      PRICTT.26
      SIGN12=D.5*IF(2(+DFI2(+FI4(+DFI4((                                PRICTT.27
      SIGN34=0.5*(FI6(+DFI6(+F(8(+DFI8(I                                PRICTT.28
      SIGS12=0.5*(FI1(+DF(1(+FI3(+DFI3((                                PRICTT.29
      SIGS34=D.5*(F(5(+DF(5(+FI7(+DFI7()                                PRICTT.30
      IFISIGN12 .GT. 0.0 .AMD. SIGN34 .LT. 0.D( GO TO 401               PRICTT.31
C                                                                       PRICTT.32
C     TENSION CASE                                                      PRICTT.33
      CII(=AKS/3.0-AKS/10000000.D                                       PRICTT.34
      CI2(=AKN/3.0-AKN/10000000.D                                       PRICTT.35
      C(3(=AKS/6.0-AKS/10000000.0                                       PRICTT.36
      CI4(=AKN/6.0-AKN/10000000.D                                       PRICTT.37
      NINO=2                                                            PRICTT.38
      GO TO 402                                                         PRICTT.39
  401 CONTINUE                                                          PRICTT.40
C                                                                       PRICTT.41
C     COMPRESSION,ELASTIC CASE                                          PRICTT.42
      FU=PARAFR(3(                                                      PRICTT.43
      SHEAR=0.5*(ABS(SIGS12)+ABS(SIGS34)(                               PRICTT.44
      STREG=FU*0.5*(ABS(SIGN12(+ABS(SIGN34((                            PRICTT.45
      (F(SHEAR .LT. STREG) RETURN                                       PRICTT.46
```

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C                                                                       PRICTT.47
C     COMPRESSION.SHEAR FAILURE                                         PRICTT.48
      NIND=1                                                            PRICTT.49
      C(1)=AKS/3.0-AKS/10000000.0                                       PRICTT.50
      C(2)=0.0                                                          PRICTT.51
      C(3)=AKS/6.0-AKS/10000000.0                                       PRICTT.52
      C(4)=0.0                                                          PRICTT.53
  402 CONTINUE                                                          PRICTT.54
      RETURN                                                            PRICTT.55
      END                                                               PRICTT.56
```

```
      SUBROUTINE PEXPAN(PARAFR,PAREX,SA,UE,DTU,V,F,C,NIND)              PEXPAN.2
C                                                                       PEXPAN.3
C     ******************************************************************PEXPAN.4
C     CHECK IF EXPANSION JOINT IS YIELD,OR IF THE BRIDGE FALLS OFF      PEXPAN.5
C     SUPPORT,AND FORM TANGENT MODULUS CONSTANTA-C(4)                   PEXPAN.6
C     ******************************************************************PEXPAN.7
C                                                                       PEXPAN.8
      DIMENSION PAREX(4),SA(8,8),UE(4),DTU(8),F(8),C(4),V(8),DF(8)      PEXPAN.9
      DIMENSION PARAFR(4)                                               PEXPAN.10
C     CHECK IF THE SUPERSTRUCTURE FALLS OFF                             PEXPAN.11
      SEAT=PAREX(2)                                                     PEXPAN.12
      AKS=PARAFR(1)                                                     PEXPAN.13
      AKN=PARAFR(2)                                                     PEXPAN.14
      IF(PAREX(4) .EQ. 0.0) GO TO 401                                   PEXPAN.15
C                                                                       PEXPAN.16
C     LEFT LOWER                                                        PEXPAN.17
      SLIP=UE(4)-UE(1)                                                  PEXPAN.18
      IF(SLIP .GT. SEAT) GO TO 402                                      PEXPAN.19
      GO TO 403                                                         PEXPAN.20
  401 CONTINUE                                                          PEXPAN.21
C                                                                       PEXPAN.22
C     RIGHT HAND LOWER                                                  PEXPAN.23
      SLIP=UE(2)-UE(3)                                                  PEXPAN.24
      IF(SLIP .GT. SEAT) GO TO 402                                      PEXPAN.25
      GO TO 403                                                         PEXPAN.26
  402 CONTINUE                                                          PEXPAN.27
      PRINT 501                                                         PEXPAN.28
      STOP                                                              PEXPAN.29
  403 CONTINUE                                                          PEXPAN.30
C                                                                       PEXPAN.31
C     SET LINEAR INDICATOR                                              PEXPAN.32
      NIND=0                                                            PEXPAN.33
C     CALCULATE APPARENT ELASTIC INCREMENTAL END FORCES FORCES OF(8)     PEXPAN.34
      DO 301 I=1,8                                                      PEXPAN.35
      XA=0.0                                                            PEXPAN.36
      DO 302 J=1,8                                                      PEXPAN.37
      XA=XA+SA(I,J)*DTU(J)                                              PEXPAN.38
  302 CONTINUE                                                          PEXPAN.39
      DF(I)=XA                                                          PEXPAN.40
  301 CONTINUE                                                          PEXPAN.41
C                                                                       PEXPAN.42
C     AVERAGE APPARENT FORCES AT CENTER OF ELEMENT                      PEXPAN.43
      SIGN12=0.5*(F(2)+DF(2)+F(4)+DF(4))                                PEXPAN.44
      SIGN34=0.5*(F(6)+DF(6)+F(8)+DF(8))                                PEXPAN.45
      SIGS12=0.5*(F(1)+DF(1)+F(3)+DF(3))                                PEXPAN.46
      SIGS34=0.5*(F(5)+DF(5)+F(7)+DF(7))                                PEXPAN.47
      IF(SIGN12 .GT. 0.0 .AND. SIGN34 .LT. 0.0) GO TO 404               PEXPAN.48
C                                                                       PEXPAN.49
C     TENSION CASE                                                      PEXPAN.50
      C(1)=AKS/3.0-AKS/10000000.0                                       PEXPAN.51
      C(2)=AKN/3.0-AKN/10000000.0                                       PEXPAN.52
      C(3)=AKS/6.0-AKS/10000000.0                                       PEXPAN.53
      C(4)=AKN/6.0-AKN/10000000.0                                       PEXPAN.54
      NINO=2                                                            PEXPAN.55
      GO TO 411                                                         PEXPAN.56
  404 CONTINUE                                                          PEXPAN.57
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C                                                                       PEXPAN.58
C     COMPRESSION,ELASTIC CASE                                          PEXPAN.59
      FU=PAREX(3)                                                       PEXPAN.60
      STREG=FU*0.5*(ABS(SIGN12)+ABS(SIGN34))                           PEXPAN.61
      SHEAR=0.5*(ABS(SIGS12)+ABS(SIGS34))                              PEXPAN.62
      IF(SHEAR .LT. STREG) RETURN                                       PEXPAN.63
C                                                                       PEXPAN.64
C     COMPRESSION.SHEAR FAILURE,LEFT LOWER                              PEXPAN.65
      GAP=PAREX(1)                                                      PEXPAN.66
      IF(PAREX(4) .NE. 0.0) GO TO 405                                   PEXPAN.67
      SHORT=UE(4)-UE(1)                                                 PEXPAN.68
      IF(SHORT .GE. GAP) GO TO 407                                      PEXPAN.69
      GO TO 408                                                         PEXPAN.70
  407 CONTINUE                                                          PEXPAN.71
      RV=V(1)-V(4)                                                      PEXPAN.72
      IF(RV .GT. 0.0) RETURN                                            PEXPAN.73
  408 CONTINUE                                                          PEXPAN.74
C                                                                       PEXPAN.75
C     SLIPPAGE OCCUR                                                    PEXPAN.76
      C(1)=AKS/3.0-AKS/10000000.0                                       PEXPAN.77
      C(2)=0.0                                                          PEXPAN.78
      C(3)=AKS/6.0-AKS/10000000.0                                       PEXPAN.79
      C(4)=0.0                                                          PEXPAN.80
      NINO=1                                                            PEXPAN.81
      GO TO 411                                                         PEXPAN.82
C                                                                       PEXPAN.83
C     RIGHT HAND LOWER CASE                                             PEXPAN.84
  405 CONTINUE                                                          PEXPAN.85
      SHORT=UE(3)-UE(2)                                                 PEXPAN.86
      IF(SHORT .GE. GAP) GO TO 409                                      PEXPAN.87
      GO TO 410                                                         PEXPAN.88
  409 CONTINUE                                                          PEXPAN.89
      RV=V(3)-V(2)                                                      PEXPAN.90
      IF(RV .GT. 0.0) RETURN                                            PEXPAN.91
  410 CONTINUE                                                          PEXPAN.92
      C(1)=AKS/3.0-AKS/10000000.0                                       PEXPAN.93
      C(2)=0.0                                                          PEXPAN.94
      C(3)=AKS/6.0-AKS/10000000.0                                       PEXPAN.95
      C(4)=0.0                                                          PEXPAN.96
      NINO=1                                                            PEXPAN.97
  411 CONTINUE                                                          PEXPAN.98
  501 FORMAT(' BRIDGE FALLS OFF')                                       PEXPAN.99
      RETURN                                                            PEXPAN.100
      END                                                               PEXPAN.101
```

```
      SUBROUTINE PBOUND(PARABO,DTU,F,C,NIND)                            PBOUND.2
C     ******************************************************************PBOUND.3
C     CHCEK IF BOUNDARY JOINT IS YIELD,AND THEN FORM YIELD STIFFNESS-C  PBOUND.4
C     ******************************************************************PBOUND.5
      DIMENSION PARABO(2),DTU(8),F(8),C(1),PSSIG(1)                     PBOUND.6
      NIND=0                                                            PBOUND.7
C                                                                       PBOUND.8
C     CALCULATE UPPER LIMIT AND LOWER LIMIT LINES                       PBOUND.9
      E1=PARABO(1)                                                      PBOUND.10
      FY=PARABO(2)                                                      PBOUND.11
      FU=FY                                                             PBOUND.12
      FL=-FY                                                            PBOUND.13
C     APPARENT END FORCES DUE TO ELASTIC INCREMENT                      PBOUND.14
      PSSIG(1)=F(1)+DTU(1)*E1                                           PBOUND.15
C     CHECK YIELD CONDITION                                             PBOUND.16
      IF(PSSIG(1) .LT. FU .AND. PSSIG(1) .GT. FU) RETURN                PBOUND.17
C                                                                       PBOUND.18
C     YIELD                                                             PBOUND.19
      C(1)=0.9*E1                                                       PBOUND.20
      NINO=1                                                            PBOUND.21
      RETURN                                                            PBOUND.22
      END                                                               PBOUND.23
```

```
      SUBROUTINE STEP(ID,X,Y,PARASO,PARACO,PARAFR,PARAEX,PARABO,COPROP,  STEP.2
     1K2S,CMP,(X,(BC,SLY,OLX,OLY,C,AEN,U,Y,ACC,DU,DV,OA,TEPS,OEPS,      STEP.3
     2PEPS,OS(G,S(G,PS(G,(NFW,WFX,YBAR,WFY,NPASS,NINO,HS(G,SY,AT,BT,    STEP.4
     3TRU,TRY,TRA,US,NELW,NTW,GS,NUMNP,NEQ,MBAND,KL(N,NUMEL)            STEP.5
C                                                                       STEP.6
C     ********************************************************************STEP.7
C     STEP-BY-STEP (INTEGRATION- -NEWMARK LINEAR OR CONSTANT            STEP.8
C     ACCELERATION METHOD                                               STEP.9
C     ********************************************************************STEP.10
C                                                                       STEP.11
      COMMON/SPEC(L/ISTOP                                               STEP.12
      COMMON/T(TLE/HEAD(12),EQNAME(12)                                  STEP.13
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUNATE,NUMATB,NUMGE,N(NTCV,THICKSTEP.14
     1,NPLAN                                                            STEP.15
      COMMON/T(ME/JUMP,T,OT,MPRTM,NTAPE,KPRINT                          STEP.16
      COMMON/ABS/UGXT,UGYT,VGXT,YGYT,OACCX,OACCY                        STEP.17
      COMMON/OMEGA/OMEGA1,OMEGA2,NF1,NF2                                STEP.18
      O(MENSION (O(3,1),X(1),Y(1),PARASO(8,1),PARACO(5,1),PARAFR(4,1),  STEP.19
     1PARAEX(4,1),PARABO(2,1),K2S(20,1),CMP(9,1),IX(6,1),(BC(4,1),U(1),STEP.20
     2V(1),ACC(1),OU(1),OY((1),DA(1),TEPS(3,1),OEPS(3,1),PEPS(3,1),     STEP.21
     3OS(G(8,1),S(G(8,1),PS(G(4,1),WFX(1),YBAR(1),WFY(1),NPASS(1),      STEP.22
     4N(NO(1),AEN(NEQ,1),SY(6,6),AT(1),BT(1),TRU(1),TRY(1),TRA(1),US(1) STEP.23
      O(MENSION U2G(9,2),OLX(1),OLY(1),C(5,1),NELW(10),(NFW(1)          STEP.24
      COMMON/EQ/DURANA,OOT                                              STEP.25
      O(MENSION HS(G(9,NUMEL)                                           STEP.26
      O(MENSION COPROP(3,1),SLY(1)                                      STEP.27
      REAL K2S                                                          STEP.28
      READ 1,EQNAME                                                     STEP.29
      PRINT 101,EQNAME                                                  STEP.30
      READ 2,EQMUL,OTEQ,OT,DUREQ,DURANA,VERTAC,MPRTM,NTAPE,KPRINT       STEP.31
      PR(NT 102,EQMUL,OTEQ,OT,DUREQ,DURANA,VERTAC,MPRTM,NTAPE,KPRINT    STEP.32
      OOT=OT*NTAPE                                                      STEP.33
      READ 3,X(1,X(2,NSLOPE                                             STEP.34
      WR(TE(6,103) X(1,X(2,NSLOPE                                       STEP.35
      WR(TE(6,105) OMEGA1,OMEGA2                                        STEP.36
      T1=X(2*OMEGA1-X(1*OMEGA2                                          STEP.37
      T2=2.0*OMEGA1*OMEGA2                                              STEP.38
      TC=OMEGA1**2-OMEGA2**2                                            STEP.39
      ALFA=T1*T2/TC                                                     STEP.40
      T3=2.0*(X(1*OMEGA1-X(2*OMEGA2)                                    STEP.41
      BETA=T3/TC                                                        STEP.42
C                                                                       STEP.43
C     FORM CONSTANTS FOR (NTEGRATION METHOD                             STEP.44
      (F(NSLOPE .EQ. 0) GO TO 402                                       STEP.45
C                                                                       STEP.46
C     LINEAR ACCELERATION METHOD                                        STEP.47
      TEMP1=3.0*ALFA*OT+6.0                                             STEP.48
      TEMP2=OT*OT+3.0*BETA*OT                                           STEP.49
      C1=TEMP1/TEMP2                                                    STEP.50
      C2=ALFA-BETA*C1                                                   STEP.51
      C3=OT/(OT+3.0*BETA)                                               STEP.52
      AT1=6.0/OT                                                        STEP.53
      AT2=3.0                                                           STEP.54
      BT1=3.0                                                           STEP.55
      BT2=OT/2.0                                                        STEP.56
      COM=6.0/OT/OT                                                     STEP.57
      COM1=OT*OT/3.0                                                    STEP.58
      COM2=OT*OT/6.0                                                    STEP.59
      03=3.0/OT                                                         STEP.60
      GO TO 401                                                         STEP.61
  402 CONTINUE                                                          STEP.62
C                                                                       STEP.63
C     CONSTANT ACCELERAT(ON METHOD                                      STEP.64
      TEMP1=2.0*ALFA*OT+4.0                                             STEP.65
      TEMP2=OT*OT+2.0*BETA*OT                                           STEP.66
      C1=TEMP1/TEMP2                                                    STEP.67
      C2=ALFA-BETA*C1                                                   STEP.68
      C3=OT/(OT+2.0*BETA)                                               STEP.69
      AT1=4.0/OT                                                        STEP.70
      AT2=2.0                                                           STEP.71
      BT1=2.0                                                           STEP.72
      BT2=0.0                                                           STEP.73
      COM=4.0/OT/OT                                                     STEP.74
      COM1=OT*OT/4.0                                                    STEP.75
      COM2=OT*OT/4.0                                                    STEP.76
      03=2.0/OT                                                         STEP.77
  401 CONTINUE                                                          STEP.78
C                                                                       STEP.79
      ACCY=0.0                                                          STEP.80
      G=386.0T                                                          STEP.81
      DO 301 (=1,9                                                      STEP.82
      DO 301 J=1,2                                                      STEP.83
      U2G(I,J)=0.0                                                      STEP.84
  301 CONT(NUE                                                          STEP.85
C                                                                       STEP.86
      READ 4,(U2G((,1),(=2,9)                                           STEP.87
      PR(NT 104,(U2G((,1),(=1,9)                                        STEP.88
      ACCX=U2G(2,1)*EQMUL*G                                             STEP.89
      (F(VERTAC .EQ. 0.0) GO TO 403                                     STEP.90
      READ 4,(U2G((,2),(=2,9)                                           STEP.91
      PR(NT 104,(U2G((,2),(=1,9)                                        STEP.92
      ACCY=U2G(2,2)*EQMUL*G                                             STEP.93
  403 CONT(NUE                                                          STEP.94
      DUR1=T.0*OTEQ                                                     STEP.95
      DUR=8.0*OTEQ                                                      STEP.96
      DO 302 (=1,NEQ                                                    STEP.97
      AT((=0.0                                                          STEP.98
      BT((=0.0                                                          STEP.99
  302 CONT(NUE                                                          STEP.100
C     CALCULATE AT,BT FOR 1ST STEP                                      STEP.101
      DO 303 (=1,NEQ                                                    STEP.102
      (F(OLX(() .EQ. 0.0) GO TO 303                                     STEP.103
      AT((=-AT2*ACCX                                                    STEP.104
      BT((=-BT2*ACCX                                                    STEP.105
  303 CONTINUE                                                          STEP.106
      (F(VERTAC .EQ. 0.0) GO TO 404                                     STEP.107
      DO 304 (=1,NEQ                                                    STEP.108
      (F(OLY(() .EQ. 0.0) GO TO 304                                     STEP.109
      AT((=-AT2*ACCY                                                    STEP.110
      BT((=-BT2*ACCY                                                    STEP.111
  304 CONT(NUE                                                          STEP.112
  404 CONTINUE                                                          STEP.113
C
C     IN(TIL(ZAT(ON                                                     STEP.115
      DO 305 (=1,NEQ                                                    STEP.116
      TRU((=0.0                                                         STEP.117
      TRY((=0.0                                                         STEP.118
      TRA((=0.0                                                         STEP.119
  305 CONT(NUE                                                          STEP.120
      UGXT=0.0                                                          STEP.121
      UGYT=0.0                                                          STEP.122
      VGXT=0.0                                                          STEP.123
      YGYT=0.0                                                          STEP.124
      OACCX=ACCX                                                        STEP.125
      OACCY=ACCY                                                        STEP.126
C     ********************************                                  STEP.127
C     START OF STEP-BY-STEP CYCLE                                       STEP.128
C     ********************************                                  STEP.129
 1000 T=T+OT                                                            STEP.130
      JUMP=JUMP+1                                                       STEP.131
      (F(T .GT. DURANA) GO TO 414                                       STEP.132
      (F(T .GT. DUREQ) GO TO 406                                        STEP.133
      (F(T .LE. DUR1) GO TO 405                                         STEP.134
      U2G(1,1)=U2G(9,1)                                                 STEP.135
      U2G(1,2)=U2G(9,2)                                                 STEP.136
      READ 4,(U2G((,1),(=2,9)                                           STEP.137
      PR(NT 104,(U2G((,1),(=1,9)                                        STEP.138
      (F(VERTAC .NE. 0.0) GO TO 453                                     STEP.139
      GO TO 454                                                         STEP.140
  453 READ 4,(U2G((,2),(=2,9)                                           STEP.141
      PR(NT 104,(U2G((,2),(=1,9)                                        STEP.142
  454 CONT(NUE                                                          STEP.143
      DUR1=DUR1+DUR                                                     STEP.144
  405 CONTINUE                                                          STEP.145
C                                                                       STEP.146
C     (NTERPOLAT(ON OF EARTHQUAKE INPUT (F OT NOT EQUAL TO OTEQ         STEP.147
      TEMP=(DUR1-T)/OTEQ                                                STEP.148
      (NO=TEMP                                                          STEP.149
      FRACT=TEMP-FLOAT((NO)                                             STEP.150
      (NO=9-(NO                                                         STEP.151
      ACCX=(U2G((NO,1)+FRACT*(U2G((NO-1,1)-U2G((NO,1)))*EQMUL*G         STEP.152
      ACCY=(U2G((NO,2)+FRACT*(U2G((NO-1,2)-U2G((NO,2)))*EQMUL*G         STEP.153
      GO TO 407                                                         STEP.154
  406 CONTINUE                                                          STEP.155
      ACCX=0.0                                                          STEP.156
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      ACCY=0.0                                                          STEP.157
  407 CONTINUE                                                          STEP.158
      DTACCX=OACCX-ACCX                                                 STEP.159
      DTACCY=OACCY-ACCY                                                 STEP.160
      DO 351 I=1,NEQ                                                    STEP.161
  351 DU(I)=0.0                                                         STEP.162
C                                                                       STEP.163
C     INCRENENTAL FORCE VECTOR-DU(I)                                    STEP.164
      DO 306 I=1,NEQ                                                    STEP.165
      DU(I)=DLX(I)*(DTACCX+AT(I)+C2*BT(I))                              STEP.166
      DU(I)=DU(I)+DLY(I)*(DTACCY+AT(I)+C2*BT(I))                        STEP.167
  306 CONTINUE                                                          STEP.168
C                                                                       STEP.169
C     INTEGRATION OF EQ ACCELERATION RECORD INTO VELO. AND DISP. OF     STEP.170
C     GROUND MOTION                                                     STEP.171
      UGXT=UGXT+DT*VGXT+COM1*OACCX+COM2*ACCX                            STEP.172
      UGYT=UGYT+DT*VGYT+COM1*OACCY+COM2*ACCY                            STEP.173
      VGXT=VGXT+0.5*DT*(OACCX+ACCX)                                     STEP.174
      VGYT=VGYT+0.5*DT*(OACCY+ACCY)                                     STEP.175
      OACCX=ACCX                                                        STEP.176
      OACCY=ACCY                                                        STEP.177
      IF(KLIN .EQ. 1) GO TO 430                                         STEP.178
      IF(JUMP .NE. 1) GO TO 451                                         STEP.179
      REWIND 3                                                          STEP.180
      READ(3) ((AEN(I,J),I=1,NEQ),J=1,MBAND)                            STEP.181
  430 CONTINUE                                                          STEP.182
C     FORM EFFECTIVE MATRIX KBAR=K+C1*M                                 STEP.183
      DO 311 I=1,NEQ                                                    STEP.184
      TEMP=C1*(OLX(I)+OLY(I))                                           STEP.185
      AEN(I,1)=AEN(I,1)+TEMP                                            STEP.186
  311 CONTINUE                                                          STEP.187
  451 CONTINUE                                                          STEP.188
      CALL TRIA(AEN,NEQ,MBAND)                                          STEP.189
      CALL BACKS(AEN,DU,NEQ,MBAND)                                      STEP.190
C     ******************************************************************STEP.191
C     INCREMENTAL DISPLACEMENT,VELOCITY,AND ACCELERATION IS CALCULATED  STEP.192
C     ******************************************************************STEP.193
      DO 307 I=1,NEQ                                                    STEP.194
      DISP=C3*DU(I)+C3*BETA*BT(I)                                       STEP.195
      DU(I)=DISP                                                        STEP.196
      VEL=DISP*D3-BT(I)                                                 STEP.197
      DV(I)=VEL                                                         STEP.198
      ACCE=DISP*CON-AT(I)                                               STEP.199
      DA(I)=ACCE                                                        STEP.200
  307 CONTINUE                                                          STEP.201
C                                                                       STEP.202
C     THE TOTAL RELATIVE RESPONSE                                       STEP.203
      DO 308 I=1,NEQ                                                    STEP.204
      TRU(I)=TRU(I)+DU(I)                                               STEP.205
      TRV(I)=TRV(I)+DV(I)                                               STEP.206
      TRA(I)=TRA(I)+DA(I)                                               STEP.207
      IF(TRU(I) .LE. 100.0) GO TO 308                                   STEP.208
      PRINT 500,JUMP,I,TRU(I)                                           STEP.209
  500 FORMAT(*1 STRUCTURE YIELD,ANALYSIS QUIT,AT JUMP,I,TRU=*,215,E12.4)STEP.210
      DURANA=T-DT*FLOAT(NTAPE)                                          STEP.211
      ISTOP=1                                                           STEP.212
      CALL PRINTR(IO,IX,TRU,TRV,ACC,TEPS,PEPS,SIG,PSIG,WFX,YBAR,WFY,    STEP.213
     1            NPASS,NIND,HSIG,NTW,NUMELE)                           STEP.214
      RETURN                                                            STEP.215
  308 CONTINUE                                                          STEP.216
      DO 320 J=1,NUMEL                                                  STEP.217
      DO 321 I=1,3                                                      STEP.218
  321 DEPS(I,J)=0.0                                                     STEP.219
      DO 322 I=1,8                                                      STEP.220
  322 DSIG(I,J)=0.0                                                     STEP.221
  320 CONTINUE                                                          STEP.222
C                                                                       STEP.223
C     CALCULATE STRAIN                                                  STEP.224
      CALL STRAIN(IO,X,Y,IX,DU,TEPS,DEPS,PEPS)                          STEP.225
C                                                                       STEP.226
C     CALCULATE STRESS                                                  STEP.227
      CALL STRESS(IX,DU,DEPS,DSIG,SIG,PSIG)                             STEP.228
C     NO WALL                                                           STEP.229
      IF(NTW .EQ. 0) GO TO 420                                          STEP.230
C                                                                       STEP.231
C     CALCULATE WALL FORCES                                             STEP.232
      CALL WFORCE(Y,IX,SIG,NELW,INFW,WFX,YBAR,WFY,NTW)                  STEP.233
C                                                                       STEP.234
C     TOTAL RESPONSE OF ALL NODAL POINT FROM STATIC                     STEP.235
  420 CONTINUE                                                          STEP.236
      IF(JUMP .NE. 1) GO TO 452                                         STEP.237
      DO 352 I=1,NEQ                                                    STEP.238
  352 US(I)=U(I)                                                        STEP.239
      GO TO 415                                                         STEP.240
  452 CONTINUE                                                          STEP.241
      DO 353 I=1,NEQ                                                    STEP.242
  353 US(I)=0.0                                                         STEP.243
  415 CONTINUE                                                          STEP.244
      DO 309 I=1,NUMNP                                                  STEP.245
      NX=IO(1,I)                                                        STEP.246
      IF(NX .EQ. 0) GO TO 408                                           STEP.247
      IF(NX .GT. NEQ) STOP                                              STEP.248
      TRU(NX)=TRU(NX)+US(NX)                                            STEP.249
      U(NX)=TRU(NX)+UGXT                                                STEP.250
      V(NX)=TRV(NX)+VGXT                                                STEP.251
      ACC(NX)=TRA(NX)+ACCX                                              STEP.252
  408 CONTINUE                                                          STEP.253
      NY=IO(2,I)                                                        STEP.254
      IF(NY .EQ. 0) GO TO 409                                           STEP.255
      TRU(NY)=TRU(NY)+US(NY)                                            STEP.256
      U(NY)=TRU(NY)+UGYT                                                STEP.257
      V(NY)=TRV(NY)+VGYT                                                STEP.258
      ACC(NY)=TRA(NY)+ACCY                                              STEP.259
  409 CONTINUE                                                          STEP.260
      NT=IO(3,I)                                                        STEP.261
      IF(NT .EQ. 0) GO TO 309                                           STEP.262
      TRU(NT)=TRU(NT)+US(NT)                                            STEP.263
      U(NT)=TRU(NT)                                                     STEP.264
      V(NT)=TRV(NT)                                                     STEP.265
      ACC(NT)=TRA(NT)                                                   STEP.266
  309 CONTINUE                                                          STEP.267
C                                                                       STEP.268
C     PRINT OUT RESULTS                                                 STEP.269
      NUMELE=NUMEL                                                      STEP.270
      CALL PRINTR(IO,IX,TRU,TRV,ACC,TEPS,PEPS,SIG,PSIG,WFX,YBAR,WFY,    STEP.271
     1            NPASS,NIND,HSIG,NTW,NUMELE)                           STEP.272
C                                                                       STEP.273
C     CALCULATE AT(I),BT(I),FOR USE IN NEXT STEP                        STEP.274
      DO 310 I=1,NEQ                                                    STEP.275
      AT(I)=AT1*TRV(I)+AT2*TRA(I)                                       STEP.276
  310 CONTINUE                                                          STEP.277
      DO 313 I=1,NEQ                                                    STEP.278
      BT(I)=BT1*TRV(I)+BT2*TRA(I)                                       STEP.279
  313 CONTINUE                                                          STEP.280
C                                                                       STEP.281
C     CHECK IF IT IS A LINEAR OR NONLINEAR ANALYSIS                     STEP.282
      IF(KLIN .NE. 0) GO TO 412                                         STEP.283
C                                                                       STEP.284
C     LINEAR ANALYSIS                                                   STEP.285
      REWIND 3                                                          STEP.286
      READ(3) ((AEN(I,J),I=1,NEQ),J=1,MBAND)                            STEP.287
C     FORM EFFECTIVE MATRIX                                             STEP.288
      DO 312  I=1,NEQ                                                   STEP.289
      TEMP=C1*(OLX(I)+OLY(I))                                           STEP.290
      AEN(I,1)=AEN(I,1)+TEMP                                            STEP.291
  312 CONTINUE                                                          STEP.292
      GO TO 413                                                         STEP.293
  412 CONTINUE                                                          STEP.294
      CALL NTSTIF(X,Y,PARASO,PARACO,PARAFR,PARAEX,PARABO,COPROP,K2S,    STEP.295
     1CMP,IX,IBC,SLV,C,AEN,U,V,DU,TEPS,DEPS,PEPS,DSIG,SIG,PSIG,NPASS,   STEP.296
     2NINO,SY,GS,NEQ,MBAND,NUMEL,KLIN)                                  STEP.297
  413 GO TO 1000                                                        STEP.298
  414 CONTINUE                                                          STEP.299
      RETURN                                                            STEP.300
    1 FORMAT(12A6)                                                      STEP.301
    2 FORMAT(6F10.5,3I5)                                                STEP.302
    3 FORMAT(2F10.6,I5)                                                 STEP.303
    4 FORMAT(8F7.4)                                                     STEP.304
  101 FORMAT(1H1,12A6)                                                  STEP.305
  102 FORMAT(* EARTHQUAKE NULTIPLICATION FACTOR  *F10.5/                STEP.306
     1       * TINE INTERVAL ON DATA CARDS       *,F10.5/               STEP.307
     2       * TINE INCREMENT OF THE ANALYSIS    *,F10.5/               STEP.308
     3       * DURATION OF EARTHQUAKE            *,F10.5/               STEP.309
     4       * DURATION OF ANALYSIS              *,F10.5/               STEP.310
     5       * WITH OR WITHOUT VERTICAL EQ       *,F10.5/               STEP.311
     6       * TINE INCREMENT OF PRINT OUT/OT    *,I10/                 STEP.312
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     7       * TIME INTERVAL FOR TAPE WRITING/DT *,I1D/                  STEP.313
     8       * TIME OF FIRST PRINT OUT/DT        *,I1D//)                STEP.314
  103 FORMAT(* DAMPING RATIO 1ST MODE          *,F10.6/                  STEP.315
     1       * DAMPING RATIO 2ND MODE          *,F10.6/                  STEP.316
     2       * CONSTANT OR LINEAR ACCELERATION*,I10//)                   STEP.317
  104 FORMAT(* INPUT EARTHQUAKE*/19F7.4))                                STEP.318
  105 FORMAT(* TWO CONTROL FREQ FOR DAMP,OMEGA1,OMEGA2*/(2E12.4))        STEP.319
      END                                                                STEP.320
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      SUBROUTINE MODES(NEQ,MBAND,NBLOCK,NF,MTOT,N18)                     MODES.2
C     ********************************************************************MODES.3
C     PROGRAM TO COMPUTE 1ST TWO LOWEST FREQUENCIES FOR CALCULATE        MODES.4
C     DAMPING COEFFICIENTS,ALFA,BETA                                     MODES.5
C     ********************************************************************MODES.6
      COMMON A(35500)                                                    MODES.7
      COMMON/OMEGA/OMEGA1,OMEGA2,NF1,NF2                                 MODES.8
      COMMON/TAPES/NSTIF,NMASS                                           MODES.9
      MTOT=35500                                                         MODES.10
      NSTIF=3                                                            MODES.11
      NMASS=4                                                            MODES.12
      WRITE(6,101) NEQ,MBAND,NF                                          MODES.13
      NIM=3                                                              MODES.14
      NC=NF+NIM                                                          MODES.15
      NWA=NEQ*MBAND                                                      MODES.16
      NM2=N18+NWA                                                        MODES.17
      NM3=NM2+NEQ                                                        MODES.18
      NM4=NM3+NEQ                                                        MODES.19
      NM5=NM4+NEQ                                                        MODES.20
      NM6=NM5+NEQ                                                        MODES.21
      NM7=NM6+NEQ*NC                                                     MODES.22
      NM8=NM7+NEQ*NC                                                     MODES.23
      NM9=NM8+NC                                                         MODES.24
      NM10=NM9+NC                                                        MODES.25
      NM11=NM10+NC                                                       MODES.26
      NM12=NM11+NC                                                       MODES.27
      NM13=NM12+NC                                                       MODES.28
      IF(MTOT-NM13) 401,402,402                                          MODES.29
  401 WRITE(6,102) NM13                                                  MODES.30
      STOP                                                               MODES.31
  402 CONTINUE                                                           MODES.32
      CALL SECANTD(A(N18),A(NM2),A(NM3),A(NM4),A(NM5),A(NM6),A(NM7),     MODES.33
     1A(NM8),A(NM9),A(NM10),A(NM11),A(NM12),NEQ,MBAND,NWA,NF,NC)         MODES.34
      OMEGA1=A(NM8+NF1-1)                                                MODES.35
      OMEGA2=A(NM8+NF2-1)                                                MODES.36
      OMEGA1=6.28318/OMEGA1                                              MODES.37
      OMEGA2=6.28318/OMEGA2                                              MODES.38
       RETURN                                                            MODES.39
  101 FORMAT(*1PROBLEM INFORMATION      *,//                             MODES.40
     1       * NO. OF EQUATIONS         *,I4/                           MODES.41
     2       * NO. OF BANDWIDTH OF A    *,I4/                           MODES.42
     3       * NO. OF FREQUENCIESREQ    *,I4)                           MODES.43
  102 FORMAT(* FOR EXECUTION NEED TO INCREASE MTOT TO*,I6)               MODES.44
      END                                                                MODES.45
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      SUBROUTINE SECANTD (A,B,V,MAXA,N,VV,WW,ROOT,T(M,ERRVL,ERRVR,       MODES.46
     *                    NITE,N,MA,NWA,NROOT,NC)                        MODES.47
C                                                                        MODES.48
      COMMON/TAPES/NSTIF,NMASS                                           MODES.49
      DIMENSION A(NWA),B(N),V(N),VS(1),W(M),VV(N,NC),WW(N,NC),ROOT(NC),MODES.50
     *          TIM(NC),ERRVL(NC),ERRVR(NC)                             MODES.51
      INTEGER NITE(NC),MAXA(NC)                                          MODES.52
C                                                                        MODES.53
C     FOLLOWING TOLERANCES ARE SET FOR CDC 6400.....                     MODES.54
C                                                                        MODES.55
      ACTOL=1.0E-04                                                      MODES.56
      RCBTOL=1.DE-06                                                     MODES.57
      RTOL=1.DE-1D                                                       MODES.58
      RQTOL=1.0E-12                                                      MODES.59
      SCALE=2.0**900                                                     MODES.60
C                                                                        MODES.61
      NTF=5                                                              MODES.62
      IITEM=1D                                                           MODES.63
      NITEM=40                                                           MODES.64
C                                                                        MODES.65
      REWIND NMASS                                                       MODES.66
      READ (NMASS) B                                                     MODES.67
C                                                                        MODES.68
      ETA=2.0                                                            MODES.69
      NOV=D                                                              MODES.70
      JR=1                                                               MODES.71
      MSK=0                                                              MODES.72
      NWA=M*MA                                                           MODES.73
      ISC=100D                                                           MODES.74
C                                                                        MODES.75
      CALL SECOND (TIM1)                                                 MODES.76
      RA=0.D                                                             MODES.77
      RR=D.D                                                             MODES.78
      CALL BANDET (A,B,V,MAXA,N,NWA,RA,MSCH,DETA,ISC,1)                  MODES.79
      FA=DETA                                                            MODES.80
      FR=FA                                                              MODES.81
      DETR=DETA                                                          MODES.82
C                                                                        MODES.83
C     FIND LOWER BOUND ON SMALLEST EIGENVALUE                            MODES.84
C                                                                        MODES.85
      WRITE (6,1010)                                                     MODES.86
      DO 100 I=1,M                                                       MODES.87
  100 W(I)=B(I)                                                          MODES.88
      RT=0.0                                                             MODES.89
      IITE=D                                                             MODES.90
      KK=2                                                               MODES.91
  110 IITE=IITE+1                                                        MODES.92
      DO 120 I=1,M                                                       MODES.93
  120 V(I)=W(I)                                                          MODES.94
      CALL BANDET (A,B,V,MAXA,M,NWA,RA,NSCH,DETA,ISC,KK)                 MODES.95
      KK=2                                                               MODES.96
      RQT=0.0                                                            MODES.97
      DO 130 I=1,M                                                       MODES.98
  130 RQT=RQT+W(I)*V(I)                                                  MODES.99
      DO 180 I=1,N                                                       MODES.100
  180 W(I)=B(I)*V(I)                                                     MODES.101
                                                                         ---------
      RQB=D.D                                                            MODES.103
      DO 140 I=1,N                                                       MODES.104
  140 RQB=RQB+W(I)*V(I)                                                  MODES.105
      RQ=RQT/RQB                                                         MODES.106
      WRITE (6,1004) RQ                                                  MODES.107
      BS=SQRT(RQB)                                                       MODES.108
      TOL=ABS(RQ-RT)/RQ                                                  MODES.109
      IF (TOL.LT.RCBTOL) GO TO 150                                       MODES.110
      DO 160 I=1,N                                                       MODES.111
  160 W(I)=W(I)/BS                                                       MODES.112
      RT=RQ                                                              MODES.113
      IF (IITE.LT.(ITEM) GO TO 110                                       MODES.114
C                                                                        MODES.115
  150 DO 170 I=1,N                                                       MODES.116
  170 V(I)=V(I)/BS                                                       MODES.117
      RB=RQ+(1.D-AMIN1(D.1,100*TOL))                                     MODES.118
      IS=D                                                               MODES.119
  230 CALL BANDET (A,B,V,MAXA,N,NWA,RB,NSCH,DETB,ISC,1)                  MODES.120
      WRITE (6,102D) RB,NSCH                                             MODES.121
      FB=DETB                                                            MODES.122
      IF (NSCH EQ.D) GO TO 3DD
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      )S=IS+1                                                          MODES.123
      )F ))S.LE.MTF) GO TO 240                                         MODES.124
      WR)TE (6,1030)                                                   MODES.125
      STOP                                                             MODES.126
 240  R8=R8/(NSCH+1)                                                   MODES.127
      GO TO 230                                                        MODES.128
C                                                                      MODES.129
C     )TERAT(ON FOR IMO)V)DUAL ROOT                                    MODES.130
C                                                                      MODES.131
 300  WRITE (6,1040)                                                   MODES.132
      M)TE(JR)=1                                                       MODES.133
      WR)TE (6,1050) JR,NITE(JR),RA,OETA,FA,ETA,ISC                    MODES.134
      N)TE(JR)=2                                                       MODES.135
      WRITE (6,1050) JR,N)TE(JR),RB,OET8,F8,ETA,ISC                    MODES.136
C                                                                      MODES.137
C     STOP WHEN REQUIRED NO. OF ROOTS SMALLER THAN RC AND NOV=0 FOUND  MODES.138
C                                                                      MODES.139
 310  )F (NSCH.GE.MROOT) GO TO 900                                     MODES.140
C                                                                      MODES.141
      O)F=F8-FA                                                        MODES.142
      IF )OIF.NE.0.0) GO TO 320                                        MODES.143
      WR)TE )6,1060)                                                   MODES.144
      GO TO 900                                                        MODES.145
 320  OEL=F8*)R8-RA)/O)F                                               MODES.146
      RC=R8-ETA*DEL                                                    MODES.147
      TOL=RC8TOL*RC                                                    MODES.148
      IF (ABS)RC-R8).GT.TOL) GO TO 330                                 MODES.149
      WRITE (6,1070)                                                   MODES.150
      ROOT(JR)=R8                                                      MODES.151
      GO TO 400                                                        MODES.152
C                                                                      MODES.153
 330  CALL BANDET )A,8,V,MAXA,M,MWA,RC,MSCH,OETC,ISC,1)                MODES.154
      FC=OETC                                                          MODES.155
      NITE(JR)=MITE)JR)+1                                              MODES.156
      IF (JR.EQ.1) GO TO 340                                           MODES.157
      JJ=JR-1                                                          MODES.158
      00 350 K=1,JJ                                                    MODES.159
 350  FC=FC/(RC-ROOT(K))                                               MODES.160
 340  WR)TE )6,1050) JR,N)TE(JR),RC,OETC,FC,ETA,ISC                    MODES.161
C                                                                      MODES.162
C     START )MVERSE )TERATIONS                                         MODES.163
C                                                                      MODES.164
      MES=0                                                            MODES.165
      IF )JR.EQ.1) GO TO 380                                           MODES.166
      00 360 )=1,JJ                                                    MODES.167
 360  IF )ROOT)I).LT.RC) MES=MES+1                                     MODES.168
 380  NOV=MSCH-MES                                                     MODES.169
      IF )NOV.EQ.O) GO TO 370                                          MODES.170
      WRITE )6,1080) NOV                                               MODES.171
      ROOT(JR)=RC                                                      MODES.172
      IF )NOV.GT.1) MSK=1                                              MODES.173
C                                                                      MODES.174
      GO TO 400                                                        MODES.175
 370  RR=RA                                                            MODES.176
      FR=FA                                                            MODES.177
      OETR=OETA                                                        MODES.178
      RA=R8                                                            MODES.179
      FA=F8                                                            MODES.180
      OETA=OET8                                                        MODES.181
      R8=RC                                                            MODES.182
      F8=FC                                                            MODES.183
      OET8=OETC                                                        MODES.184
C                                                                      MODES.185
C     RESET ETA IF NECESSARY                                           MODES.186
C                                                                      MODES.187
      TOL=R8*ACTOL                                                     MODES.188
      IF (ABS(RA-R8).LT.TOL) ETA=ETA*2                                 MODES.189
      IF (NITE(JR).LE.MITEM) GO TO 310                                 MODES.190
      WRITE (6,1015) NITE)JR),JR                                       MODES.191
      GO TO 900                                                        MODES.192
C                                                                      MODES.193
C     CHECK FOR STORAGE                                                MODES.194
C                                                                      MODES.195
 400  IF )JR.LE.NC) GO TO 405                                          MODES.196
      WR)TE (6,1090)                                                   MODES.197
      GO TO 900                                                        MODES.198
C                                                                      MODES.199
 405  NOR=JR-1                                                         MODES.200
      CALL SECONO (T)M3)                                               MODES.201
      WRITE (6,1100) NOR                                               MODES.202
      (F (JR.EQ.1) GO TO 410                                           MODES.203
      00 420 I=1,N                                                     MODES.204
 420  V)))=1.0                                                         MODES.205
      KK=2                                                             MODES.206
 410  00 430 )=1,M                                                     MODES.207
 430  W())=B)I)*V)I)                                                   MODES.208
      )S=0                                                             MODES.209
      RTA=0.0                                                          MODES.210
      GO TO 510                                                        MODES.211
C                                                                      MODES.212
C     INVERSE )TERATION                                                MODES.213
C                                                                      MODES.214
 440  N)TE(JR)=MITE)JR)+1                                              MODES.215
      00 450 I=1,M                                                     MODES.216
 450  V())=W(I)                                                        MODES.217
      CALL BANDET )A,8,V,MAXA,M,MWA,RC,MSCH,OETC,ISC,KK)               MODES.218
      )F ))S.EQ.1) GO TO 460                                           MODES.219
      KK=2                                                             MODES.220
      RQT=0.0                                                          MODES.221
      00 470 I=1,M                                                     MODES.222
 470  RQT=RQT+W)I)*V)I)                                                MODES.223
      00 475 I=1,M                                                     MODES.224
 475  W)))=B)I)*V)I)                                                   MODES.225
      RQ8=0.0                                                          MODES.226
      00 480 I=1,M                                                     MODES.227
 480  RQ8=RQ8+W(I)*V)I)                                                MODES.228
      RQ=RQT/RQ8                                                       MODES.229
      RT=ROOT)JR)+RQ                                                   MODES.230
      WRITE )6,1110) JR,NITE(JR),RT,RQ                                 MODES.231
      TOL=RT*RQTOL                                                     MODES.232
      IF (ABS)RT-RTA).GT.TOL) GO TO 510                                MODES.233
      IS=1                                                             MODES.234
      GO TO 440                                                        MODES.235
C                                                                      MODES.236
 510  RTA=RT                                                           MODES.237
      8S=SQRT)RQ8)                                                     MODES.238
      00 490 )=1,M                                                     MODES.239
 490  W)I)=W)I)/8S                                                     MODES.240
      IF (NOR.EQ.O) GO TO 550                                          MODES.241
      00 520 K=1,NOR                                                   MODES.242
      AL=0.0                                                           MODES.243
      00 530 I=1,M                                                     MODES.244
 530  AL=AL+VV)I,K)*W(I)                                               MODES.245
      00 540 I=1,M                                                     MODES.246
 540  W)I)=W())-AL*WW(I,K)                                             MODES.247
 520  CONT)NUE                                                         MODES.248
C                                                                      MODES.249
 550  )F )NITE)JR).LE.MITEM) GO TO 440                                 MODES.250
      WRITE )6,1015) NITE(JR),JR                                       MODES.251
      GO TO 900                                                        MODES.252
C                                                                      MODES.253
 460  RQT=0.0                                                          MODES.254
      ERRT=RQ8                                                         MODES.255
      00 570 I=1,M                                                     MODES.256
 570  RQT=RQT+V(I)*W(I)                                                MODES.257
      00 560 I=1,M                                                     MODES.258
 560  W(I)=B(I)*V(I)                                                   MODES.259
      RQ8=0.0                                                          MODES.260
      00 580 I=1,M                                                     MODES.261
 580  RQ8=RQ8+V(I)*W(I)                                                MODES.262
C                                                                      MODES.263
C     OBTAIN A RATHER LARGE ERROR BOUND                                MODES.264
C                                                                      MODES.265
      RQ=RQT/RQ8                                                       MODES.266
      ROOT)JR)=ROOT)JR)+RQ                                             MODES.267
      ERR=SQRT)ERRT/RQ8)                                               MODES.268
      ERRVL)JR)=ROOT)JR)-ERR                                           MODES.269
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```
      ERRVR(JR)=ROOT(JR)*ERR                                            MODES.270
C                                                                       MODES.271
      BS=SQRT(RO8)                                                      MODES.272
      DO 590 I=1,N                                                      MODES.273
      W(I)=W(I)/BS                                                      MODES.274
  590 V(I)=V(I)/BS                                                      MODES.275
      DO 600 I=I,N                                                      MODES.276
      WW(I,JR)=W(I)                                                     MODES.277
  600 VV(I,JR)=V(I)                                                     MODES.278
C                                                                       MODES.279
      CALL SECOND (T)M2)                                                MODES.280
      T)M3=TIM2-TIM3                                                    MODES.281
      WR)TE (6,1120) TIM3                                               MODES.282
      TIM(JR)=T)M2-T(M1                                                 MODES.283
      T)MI=TIM2                                                         MODES.284
C                                                                       MODES.285
C     OECIOE STRTEGY FOR )TERATION TOWARO NEXT ROOT                     MODES.286
C                                                                       MODES.287
      TOL=RTOL*ROOT(JR)                                                 MODES.288
      IF (NOV.GT.O) GO TO 700                                           MODES.289
      )F (ABS(ROOT(JR)-R8).GT.TOL) GO TO 710                            MODES.290
      )F (RA.GT.O.O) GO TO 720                                          MODES.291
      RA=R8/2.                                                          MODES.292
      CALL BANDET (A,B,V,MAXA,M,NWA,RA,MSCH,OETA,ISC,1)                 MODES.293
      FA=OETA                                                           MODES.294
  720 R8=RA                                                             MODES.295
      F8=FA                                                             MODES.296
      OET8=DETA                                                         MODES.297
      RA=RR                                                             MODES.298
      FA=FR                                                             MODES.299
      DETA=OETR                                                         MODES.300
      GO TO 710                                                         MODES.301
C                                                                       MODES.302
  700 IF (ROOT(JR).GT.RC) NSK=1                                         MODES.303
      (F (NSK.EQ.1) GO TO 730                                           MODES.304
      )F (ABS(RC-ROOT(JR)).LT.TOL) GO TO 740                            MODES.305
      )F (ABS(ROOT(JR)-R8).LT.TOL) GO TO 750                            MODES.306
      RA=R8                                                             MODES.307
      FA=F8                                                             MODES.308
      OE7A=OET8                                                         MODES.309
  750 R8=RC                                                             MODES.310
      F8=FC                                                             MODES.311
      OET8=OETC                                                         MODES.312
      GO TO 710                                                         MODES.313
  740 IF (ABS(ROOT(JR)-R8).G7.7OL) GO TO 710                            MODES.314
      IF (RA.GT.O.O) GO TO 760                                          MODES.315
      RA=R8/2.                                                          MODES.316
      CALL BANDET (A,B,V,MAXA,N,NWA,RA,MSCH,OE7A,ISC,1)                 MODES.317
      FA=OETA                                                           MODES.318
  760 R8=RA                                                             MODES.319
      F8=FA                                                             MODES.320
      OE7B=OETA                                                         MODES.321
      RA=RR                                                             MODES.322
      FA=FR                                                             MODES.323
      DETA=OE7R                                                         MODES.324
  710 FA=FA/(RA-ROO7(JR))                                               MODES.325
      F8=F8/(R8-ROOT(JR))                                               MODES.326
      JR=JR+1                                                           MODES.327
      ETA=2.O                                                           MODES.328
      GO 7O 300                                                         MODES.329
C                                                                       MODES.330
  730 )F (RA.GT.O.O) GO 7O 780                                          MODES.331
      RA=R8/2.                                                          MODES.332
      CALL BANDET (A,B,V,MAXA,N,MWA,RA,NSCH,OE7A,ISC,1)                 MODES.333
      FA=OETA                                                           MODES.334
  780 IF (ABS(ROOT(JR)-R8).G7.7OL) GO 7O 77O                            MODES.335
      RB=RA                                                             MODES.336
      F8=FA                                                             MODES.337
      OET8=OE7A                                                         MODES.338
      RA=RR                                                             MODES.339
      FA=FR                                                             MODES.340
      DETA=OE7R                                                         MODES.341
  770 FA=FA/(RA-ROOT(JR))                                               MODES.342
      F8=F8/(R8-ROOT(JR))                                               MODES.343
      FR=FR/(RR-ROOT(JR))                                               MODES.344
      IF (ROOT(JR).LE.RC) NOV=NOV-1                                     MODES.345
      JR=JR+I                                                           MODES.346
      NITE(JR)=0                                                        MODES.347
      ROOT(JR)=RC                                                       MODES.348
      (F (NOV.GT.O) GO TO 400                                           MODES.349
      NSK=0                                                             MODES.350
      ETA=2.0                                                           MODES.351
      GO TO 300                                                         MODES.352
C                                                                       MODES.353
  900 NROOT=JR-1                                                        MODES.354
      )F (NROO7.EQ.O) RETURM                                            MODES.355
      WR)TE (6,1130)                                                    MODES.356
      WR)TE (6,1004) (ROOT(J),J=1,NROOT)                                MODES.357
      WRITE (6,1140)                                                    MODES.358
      WR)TE (6,1006) (M)TE(J),J=1,NROOT)                                MODES.359
      WR)TE (6,1150)                                                    MODES.360
      WR)TE (6,1008) (TIM(J),J=I,NROO7)                                 MODES.361
      WR)TE (6,1160)                                                    MODES.362
      WRITE (6,1004) (ERRVL(J),J=1,MROOT)                               MODES.363
      WR)TE (6,1004) (ERRVR(J),J=1,NROOT)                               MODES.364
C                                                                       MODES.365
C     ARRAMGE EIGENVALUES AMO VECTORS IN ASCEMOING ORDER                MODES.366
C                                                                       MODES.367
      )F (JR.EQ.2) GO TO 950                                            MODES.368
      JR=JR-2                                                           MODES.369
  910 IS=0                                                              MODES.370
      OO 920 )=1,JR                                                     MODES.371
      IF (ROOT(I+1).GE.ROOT(I)) GO TO 920                               MODES.372
      )S=IS+1                                                           MODES.373
      RT=ROOT(I+1)                                                      MODES.374
      ROOT()+1)=ROOT(I)                                                 MODES.375
      ROOT(I)=RT                                                        MODES.376
      OO 930 K=1,N                                                      MODES.377
      RT=VV(K,I+I)                                                      MODES.378
      VV(K,I+1)=VV(K,I)                                                 MODES.379
  930 VV(K,I)=RT                                                        MODES.380
  920 CONT)NUE                                                          MODES.381
      )F ()S.GT.O) GO TO 910                                            MODES.382
C                                                                       MODES.383
  950 WR)TE (6,1170)                                                    MODES.384
      NROOT=NSCH                                                        MODES.385
      DO 960 )=1,MROOT                                                  MODES.386
      )F (ROOT(I).LE.O.O) GO 7O 960                                     MODES.387
      ROOT(I)=SQR7(ROO7(I))                                             MODES.388
  960 CON7)NUE                                                          MODES.389
      WRITE (6,3000) NT                                                 MODES.390
      IF (NT.NE.7) M7=7                                                 MODES.391
      REWIND N7                                                         MODES.392
      WRI7E (M7) (ROOT(I),I=1,NROO7)                                    MODES.393
C                                                                       MODES.394
C     PRINT FREQUENCIES AMO MODE SHAPES                                 MODES.395
C                                                                       MODES.396
      WRI7E (6,2000)                                                    MODES.397
      OO 990 I=1,MROO7                                                  MODES.398
      PERIOO=6.2831853/ROO7(I)                                          MODES.399
      WRITE (6,2001) I,ROO7(I),PERIOO                                   MODES.400
  990 ROOT(I)=PERIOD                                                    MODES.401
C                                                                       MODES.402
      WRITE (MT) ((VV(I,J),I=1,M),J=1,MROO7)                            MODES.403
      RE7URN                                                            MODES.404
C                                                                       MODES.405
 1002 FORMAT (1H ,12E11.4)                                              MODES.406
 1004 FORMAT (1HO,6E20.12)                                              MODES.407
 1006 FORMAT (1HO,6I2O)                                                 MODES.408
 1008 FORMAT (1HO,6F20.2)                                               MODES.409
 1010 FORMAT (1H1,63HIMVERSE ITERN G)VES FOLLOWING APPROXIMA7M TO LOWESMODES.410
     1T EIGENVALUE  )                                                   MODES.411
 1015 FORMAT (41HOWE ABANDON ITERN BECAUSE NO OF ITERM IS I3.9H FOR ROOMODES.412
     1T I3 )                                                            MODES.413
 1020 FORMAT (5HOR8 = E20.12,7H NSCH = I4)                              MODES.414
 1030 FORMAT (3OHOWE BETTER CHECK THE MA7RICES  )                       MODES.415
 1040 FORMAT (1H1,4X,4HROOT,4X,4HN)TE,18X,2HRC,15X,12HOE7 (A-RC*B),15X,MODES.416
     /2HFC,13X,3HETA,4X,3HISC)                                          MODES.417
 1050 FORMAT (1HO,4X,I4,4X,I4,8X,3E22.14,F7.2,I6)                       MODES.418
 1060 FORMAT (42HO7HE OEFLATEO POLYNOMIAL HAS NO MORE ROO7S  )          MODES.419
 1070 FORMAT (29HO(RC-R8) IS SMALLER THAM TOL )                         MODES.420
 1080 FORMAT (16HOWE JUMPEO OVER (4,16H UNKNOWM ROOT(S)  )              MODES.421
 1090 FORMAT (1H1,36HNO MORE STORAGE FOR VECTORS  WE QUIT  )            MODES.422
 1100 FORMAT (1HO,34X,4HROOT,18X,2HRO,18X,4HNOR=,I2)                    MODES.423
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 1110  FORMAT (1HO,4X,I4,4X,I4,8X,2E22.14)                                    MODES.424
 1120  FORMAT (20HOTIME FOR INV ITERN F5.2)                                   MODES.425
 1130  FORMAT (20HOTHE EIGENVALUES ARE  /)                                    MODES.426
 1140  FORMAT (42HONO OF ITERATIONS FOR EACH EIGENVALUE ARE   /)              MODES.427
 1150  FORMAT (30HOTIME USED FOR EACH EIGENVALUE /)                           MODES.428
 1160  FORMAT (43HOFOLLOWING ARE ERROR BOUNDS ON EIGENVALUES )                MODES.429
 1170  FORMAT (1H1,62HWE ACCEPT FOLLOWING FREQUENCIES AND MODES ARRANGEDMODES.430
     . IN ORDER    )                                                         MODES.431
 2000  FORMAT (39H1.....PRINT OF FREQUENCIES AND PERIODS//                    MODES.432
     .  6X,4HMODE,9X,11HFREQUENCIES,13X,7HPERIODS /                         MODES.433
     .  6X,4H NO ,9X,11H (RAD/SEC) ,13X,7H ISEC)  /)                        MODES.434
 2001  FORMAT (I10,2F20.4)                                                    MODES.435
 3000  FORMAT (////46H EIGENVALUE AND EIGENVECTOR ARE STORED IN TAPE,I3)MODES.436
C                                                                           MODES.437
      END                                                                   MODES.438
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      SUBROUTINE BANOET (A,B,V,MAXA,NN,NWA,RA,NSCH,OET,ISCALE,KKI       MODES.440
C                                                                         MODES.441
      DIMENSION A(NWA),B(II),V(1),MAXA(1)                               MODES.442
      COMMON/TAPES/NSTIF,NMASS                                          MODES.443
C                                                                         MODES.444
C     TRIANGULARIZE BANDED STIFFNESS MATRIX                             MODES.445
C                                                                         MODES.446
      NR=NN-1                                                           MODES.447
      IF (KK-2) 100,700,800                                             MODES.448
C                                                                         MODES.449
  100 TOL=1.0E+07                                                       MODES.450
      RTOL=1.0E-10                                                      MODES.451
      SCALE=2.0**900                                                    MODES.452
      NTF=3                                                             MODES.453
      IS=1                                                              MODES.454
  120 REWIND NSTIF                                                      MODES.455
      READ (NSTIF) A                                                    MODES.456
      DO 140 I=1,NN                                                     MODES.457
  140 A(I)=A(I)-RA*B(I)                                                 MODES.458
  160 IF (NWA.EQ.NN) GO TO 230                                          MODES.459
      DO 200 N=1,NR                                                     MODES.460
      IH=N+NWA-NN                                                       MODES.461
  210 IF (A(IH)) 220,215,220                                            MODES.462
  215 IH=IH-NN                                                          MODES.463
      GO TO 210                                                         MODES.464
  220 MAXA(N)=IH                                                        MODES.465
      PIV=A(N)                                                          MODES.466
      IF (PIV) 221,2..6,221                                             MODES.467
  221 IL=N+NN                                                           MODES.468
      L=N                                                               MODES.469
      DO 240 I=IL,IH,NN                                                 MODES.470
      L=L+1                                                             MODES.471
      C=A(I)                                                            MODES.472
      IF (C) 225,240,225                                                MODES.473
  225 C=C/PIV                                                           MODES.474
      IF (ABS(C).LT.TOL) GO TO 235                                      MODES.475
  226 IS=IS+1                                                           MODES.476
      IF (IS.LE.NTF) GO TO 245                                          MODES.477
      WRITE (6,10001 NTF                                                MODES.478
      STOP                                                              MODES.479
  245 RA=RA*(1.0-RTOL)                                                  MODES.480
      GO TO 120                                                         MODES.481
  235 J=L-I                                                             MODES.482
      DO 260 K=I,IH,NN                                                  MODES.483
  260 A(K+J)=A(K+J)-C*A(K)                                              MODES.484
      A(I)=C                                                            MODES.485
  240 CONTINUE                                                          MODES.486
  200 CONTINUE                                                          MODES.487
  230 IF (A(NN).NE.0.0) GO TO 280                                       MODES.488
      AA=ABS(A(1))                                                      MODES.489
      DO 290 I=2,NR                                                     MODES.490
  290 AA=AA+ABS(A(I))                                                   MODES.491
      A(NN)=-(AA/NR)*1.0E-16                                            MODES.492
C                                                                       MODES.493
  280 NSCH=0                                                            MODES.494
      ISC=0                                                             MODES.495
      OET=1.0                                                           MODES.496
      DO 300 I=1,NN                                                     MODES.497
      IF (ABS(OET).LT.SCALE) GO TO 320                                  MODES.498
      OET=OET/SCALE                                                     MODES.499
      ISC=ISC+1                                                         MODES.500
  320 OET=OET*A(I)                                                      MODES.501
  300 IF (A(I).LT.0.) NSCH=NSCH+1                                       MODES.502
C                                                                       MODES.503
      IF (ISCALE.LT.1000) GO TO 340                                     MODES.504
      ISCALE=ISC                                                        MODES.505
      GO TO 900                                                         MODES.506
  340 IF (ISC-ISCALE) 350,900,370                                       MODES.507
  350 OET=OET/SCALE                                                     MODES.508
      GO TO 900                                                         MODES.509
  370 OET=OET*SCALE                                                     MODES.510
      GO TO 900                                                         MODES.511
C                                                                       MODES.512
  700 IL=NN                                                             MODES.513
      DO 400 N=1,NR                                                     MODES.514
      C=V(N)                                                            MODES.515
      V(N)=C/A(N)                                                       MODES.516
      IF (NWA-NN) 410,400,410                                           MODES.517
  410 IL=IL+1                                                           MODES.518
      IH=MAXA(N)                                                        MODES.519
      K=N                                                               MODES.520
      DO 420 I=IL,IH,NN                                                 MODES.521
      K=K+1                                                             MODES.522
  420 V(K)=V(K)-C*A(I)                                                  MODES.523
  400 CONTINUE                                                          MODES.524
      VINN=VINN/A(NN)                                                   MODES.525
C                                                                       MODES.526
  800 IF (NWA-NN) 430,900,430                                           MODES.527
  430 N=NN                                                              MODES.528
      DO 440 L=2,NN                                                     MODES.529
      N=N-1                                                             MODES.530
      IL=N+NN                                                           MODES.531
      IH=MAXA(N)                                                        MODES.532
      K=N                                                               MODES.533
      DO 460 I=IL,IH,NN                                                 MODES.534
      K=K+1                                                             MODES.535
  460 V(N)=VIN-A(I)*V(K)                                                MODES.536
  440 CONTINUE                                                          MODES.537
  900 RETURN                                                            MODES.538
 1000 FORMAT (1H1,20H TRIANG FACTORIZATN I3,32H TIMES ABONDONED,CHECK   MODES.539
     1MATRICES  I                                                       MODES.540
      END                                                               MODES.541
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      SUBROUTINE OUTPUT(IO,NUMNP,NUMEL,NEQ,NTW)                          OUTPUT.2
C                                                                        OUTPUT.3
C     ******************************************************************OUTPUT.4
C     OUTPUT THE SELECTED RESULTS IN TIME HISTORY                        OUTPUT.5
C     ******************************************************************OUTPUT.6
C                                                                        OUTPUT.7
      COMMON A(1)                                                        OUTPUT.8
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                           OUTPUT.9
      DIMENSION IO(3,NUMNP)                                              OUTPUT.10
      COMMON/BLOCK/NSD,NSS,NSW,KK1,KK2,KK3,MDIS,MSTR,MWAL,NBO,NBS,NBW    OUTPUT.11
      COMMON/EQ/OURANA,DDT                                               OUTPUT.12
C                                                                        OUTPUT.13
C      INPUT SPECIFICATION FOR OUTPUT OF RESPONSE TIME HISTORY           OUTPUT.14
      NH1=1                                                              OUTPUT.15
      NH2=NH1+3*NUMNP                                                    OUTPUT.16
      NH3=NH2+NEQ                                                        OUTPUT.17
      NH4=NH3+9*NUMEL                                                    OUTPUT.18
      NH5=NH4+3*NTW                                                      OUTPUT.19
      CALL INOUTIA(NH1(,A(NH2(,A(NH3(,A(NH4(,NUMNP,NUMEL,NEQ,NTW)        OUTPUT.20
C                                                                        OUTPUT.21
C     PACK TIME HISTORY IN BLOCK                                         OUTPUT.22
      NNTOT=2DDDD                                                        OUTPUT.23
      DDT=OT*MTAPE                                                       OUTPUT.24
      NOS=OURANA/DDT+1                                                   OUTPUT.25
      NDISB=(NNTOT-NH5-NEQ*2)/(MDIS*2)                                   OUTPUT.26
      MDISB=(MNTOT-NH5-9*NOS)/(MDIS*2(                                   OUTPUT.27
      IF(NDISB .GT. MDISB( NDISB=MDISB                                   OUTPUT.28
      IF(NDISB .GT. NOS( NDISB=NOS                                       OUTPUT.29
      NBO=(NOS-1)/NDISB+1                                                OUTPUT.30
C                                                                        OUTPUT.31
      NSTR8=(NNTOT-NH5-9*NUMEL)/(MSTR*2)                                 OUTPUT.32
      MSTRB=(NNTOT-NH5-9*NOS)/(MSTR*2)                                   OUTPUT.33
      IF(NSTRB .GT. NSTR8( NSTRB=MSTRB                                   OUTPUT.34
      IF(NSTRB .GT. NOS) NSTR8=NOS                                       OUTPUT.35
      NBS=(NDS-1)/NSTRB+1                                                OUTPUT.36
C                                                                        OUTPUT.37
      IF(NWAL .EQ. 0) GO TO 4D2                                          OUTPUT.38
      NWFB=(NNTOT-NH5-3*NTW)/NWAL                                        OUTPUT.39
      NWFB=(MNTOT-NH5-9*NOS)/NWAL                                        OUTPUT.40
      IF(NWFB .GT. MWFB( NWFB=MWFB                                       OUTPUT.41
      IF(NWFB .GT. NDS( NWFB=NDS                                         OUTPUT.42
      NBW=(NOS-1)/NWFB+1                                                 OUTPUT.43
C                                                                        OUTPUT.44
      GO TO 4D3                                                          OUTPUT.45
 4D2  CONTINUE                                                           OUTPUT.46
      NWFB=0                                                             OUTPUT.47
      NBW=0                                                              OUTPUT.48
 403  CONTINUE                                                           OUTPUT.49
      NH6=NH5+NEQ                                                        OUTPUT.50
      NH7=NH6+NEQ                                                        OUTPUT.51
      NH8=NH7+MDIS*NDISB                                                 OUTPUT.52
      NH10=NH5+9*NUMEL                                                   OUTPUT.53
      NH12=NH5+3*NTW                                                     OUTPUT.54
      NH13=NH12+MWAL*NWFB                                                OUTPUT.55
      CALL REPACK(A(NH1(,A(NH2(,A(NH3(,A(NH4(,A(NH5(,A(NH6(,A(NH7(,      OUTPUT.56
     1            A(NH8(,A(NH9(,A(NH10(,A(NH12(,NDS,NEQ,NDIS,          OUTPUT.57
     2            NDISB,NUMEL,MSTR,NSTR8,NTW,MWAL,NWFB,NBO,NBS,NBW,     OUTPUT.58
     3            NUMNP(                                                OUTPUT.59
C                                                                        OUTPUT.60
      MT=0                                                               OUTPUT.61
      NFILE=0                                                            OUTPUT.62
      IF(KK1 .EQ. 2( NFILE=NFILE+NSO*2                                   OUTPUT.63
      IF(KK2 .EQ. 2) NFILE=NFILE+NSS                                     OUTPUT.64
      IF(KK3 .EQ. 2) NFILE=NFILE+NSW                                     OUTPUT.65
      IF(NFILE .EQ. 0( GO TO 401                                         OUTPUT.66
      MT=3D                                                              OUTPUT.67
      REWIND MT                                                          OUTPUT.68
      WRITE(MT( NFILE,NDS,ODT                                            OUTPUT.69
 4D1  CONTINUE                                                           OUTPUT.70
      NH6=NH5+NDS                                                        OUTPUT.71
      NH7=NH6+8*NDS                                                      OUTPUT.72
      NH8=NH7+MDIS*NOISB                                                 OUTPUT.73
      NH9=NH7+NSTR*NSTRB                                                 OUTPUT.74
      NH10=NH7+NWAL*NWFB                                                 OUTPUT.75
      IFF=D                                                              OUTPUT.76
C                                                                        OUTPUT.77
C      OUTPUT SELECTED ABSOLUTE DISPLACENENT TIME HISTORY                OUTPUT.78
      REWIND 1D                                                          OUTPUT.79
      CALL OUTHIS(A(NH1(,A(NH2),A(NH3),A(NH4(,A(NH5),A(NH6),A(NH7),      OUTPUT.80
     1            NUMNP,NUMEL,NTW,NDS,NOIS,NOISB,NSO,NBO,1,KK1,1O,11,MT, OUTPUT.81
     2            (FF,NEQ)                                               OUTPUT.82
C                                                                        OUTPUT.83
C      OUTPUT SELECTED ABSOLUTE ACCELERATION TIME HISTORY                OUTPUT.84
      REWIND 1D                                                          OUTPUT.85
      CALL OUTHIS(A(NH1(,A(NH2),A(NH3),A(NH4(,A(NH5(,A(NH6(,A(NH7),      OUTPUT.86
     1            NUMNP,NUMEL,NTW,NDS,MDIS,NOISB,NSO,NBO,2,KK1,1D,12,MT, OUTPUT.87
     2            (FF,NEQ)                                               OUTPUT.88
C                                                                        OUTPUT.89
C      OUTPUT SELECTED STRESS TIME HISTORY                               OUTPUT.90
      REWIND 2D                                                          OUTPUT.91
      CALL OUTHIS(A(NH1(,A(NH2),A(NH3),A(NH4(,A(NH5(,A(NH6(,A(NH7),      OUTPUT.92
     1            NUMNP,NUMEL,NTW,NDS,NSTR,NSTR8,NSS,NBS,3,KK2,2O,13,MT, OUTPUT.93
     2            IFF,NEQ)                                               OUTPUT.94
C      CASE OF NO WALL                                                   OUTPUT.95
      IF(NTW .EQ. D) GO TO 404                                           OUTPUT.96
C                                                                        OUTPUT.97
C      OUTPUT SELECTED WALL FORCES TIME HISTORY                          OUTPUT.98
      REWIND 4D                                                          OUTPUT.99
      CALL OUTHIS(A(NH1(,A(NH2),A(NH3),A(NH4(,A(NH5(,A(NH6(,A(NH7),      OUTPUT.10D
     1            NUMNP,NUMEL,NTW,NDS,MWAL,NWFB,NSW,NBW,4,KK3,4O,14,MT,  OUTPUT.101
     2            IFF,NEQ(                                               OUTPUT.102
 404  CONTINUE                                                           OUTPUT.103
      RETURN                                                             OUTPUT.104
      END                                                                OUTPUT.105
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      SUBROUTINE INOUT(IO,(OIS,ISTR,IWALL,NUMNP,NUMEL,NEQ,NTW)           OUTPUT.106
C                                                                        OUTPUT.107
C     ******************************************************************OUTPUT.108
C     INPUT SPECIFICATIONS FOR OUTPUT RESPONSE TIME HISTORY              OUTPUT.109
C     ******************************************************************OUTPUT.110
C                                                                        OUTPUT.111
      DIMENSION (DISINEQN,ISTR(9,NUMEL(,IWALLI3,NTW(,ICI3(,ISI9(,IWI3(  OUTPUT.112
      DIMENSION IO(3,NUMNP(,KDI4,B)                                      OUTPUT.113
      COMMON/BLOCK/NSD,NSS,NSW,KKI,KK2,KK3,MDIS,MSTR,MWAL,NBO,NBS,NBW    OUTPUT.114
C                                                                        OUTPUT.115
C     INITILIZATION                                                      OUTPUT.116
      DO 3D1 I=1,NEQ                                                     OUTPUT.117
      (OIS((=D                                                           OUTPUT.118
 3D1  CONTINUE                                                           OUTPUT.119
      DO 302 N=1,NUMEL                                                   OUTPUT.120
      DO 302 I=1,9                                                       OUTPUT.121
      ISTR(I,N)=0                                                        OUTPUT.122
 3D2  CONTINUE                                                           OUTPUT.123
      DO 303 N=1,NTW                                                     OUTPUT.124
      DO 3D3 I=1,3                                                       OUTPUT.125
      IWALLII,N)=0                                                       OUTPUT.126
 303  CONTINUE                                                           OUTPUT.127
C                                                                        OUTPUT.128
C      READ AND PRINT DISPLACEMENT,ACCELERATION SPECIFICATION            OUTPUT.129
C     L=COLUMN NO.  KK1=I PRINT  =2 PRINT + PLOT                         OUTPUT.130
      L=0                                                                OUTPUT.131
      K=D                                                                OUTPUT.132
      READ I,KK1                                                         OUTPUT.133
 1000 CONTINUE                                                           OUTPUT.134
C     A BLOCK CARD FOR ENDING                                            OUTPUT.135
      READ 1,NP,(C                                                       OUTPUT.136
      IF(NP .GT. D( GO TO 401                                            OUTPUT.137
      IF(L .EQ. D) GO TO 4D2                                             OUTPUT.138
      WRITE(IO) KD,L                                                     OUTPUT.139
      K=K+1                                                              OUTPUT.140
      GO TO 402                                                          OUTPUT.141
 4D(  CONTINUE                                                           OUTPUT.142
      IF(K .EQ. D .AND. L.EQ. 0( WRITE(6,501)                            OUTPUT.143
      WRITE(6,1D1) NP,IC                                                 OUTPUT.144
      DO 304 (=1,3                                                       OUTPUT.145
      ((=(C((                                                            OUTPUT.146
      IF(( .EQ. D) GO TO 3D4                                             OUTPUT.147
      JJ=(D((,NP)                                                        OUTPUT.148
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      )F(JJ .LE. NEQ) GO TO 403                                          OUTPUT.149
  404 CONTINUE                                                           OUTPUT.150
      WRITE)6,502) NP,(I                                                 OUTPUT.151
      GO TO 304                                                          OUTPUT.152
  403 CONT)NUE                                                           OUTPUT.153
      IF)JJ .LE. O) GO TO 404                                            OUTPUT.154
      L=L+1                                                              OUTPUT.155
      KO(I,L)=NP                                                         OUTPUT.156
      KO)2,L)=II                                                         OUTPUT.157
      KO(3,L)+JJ                                                         OUTPUT.158
      KO(4,L)=0                                                          OUTPUT.159
      )OIS(JJ)=1                                                         OUTPUT.160
      IF(L .LT. 8) GO TO 304                                             OUTPUT.161
      WRITE)IO) KO,L                                                     OUTPUT.162
      K=K+I                                                              OUTPUT.163
      L=0                                                                OUTPUT.164
  304 CONTINUE                                                           OUTPUT.165
      GO TO 1000                                                         OUTPUT.166
C                                                                        OUTPUT.167
C     REAO ANO INPUT STRESS OUTPUT SPECIFICATION                         OUTPUT.168
  402 CONTINUE                                                           OUTPUT.169
      NSO=K                                                              OUTPUT.170
      WRITE)6,503) KK1                                                   OUTPUT.171
      L=0                                                                OUTPUT.172
      K=0                                                                OUTPUT.173
      REAO I,KK2                                                         OUTPUT.174
 2000 CONTINUE                                                           OUTPUT.175
      REAO I,NTYPE,NEL;IS                                                OUTPUT.176
C     A 8LANK CARO FOR ENOING                                            OUTPUT.177
      )F)NEL .GT. O) GO TO 405                                           OUTPUT.178
      )F(L .EQ. OI GO TO 406                                             OUTPUT.179
      WR)TE)20) KO,L                                                     OUTPUT.180
      K=K+I                                                              OUTPUT.181
      GO TO 406                                                          OUTPUT.182
  405 CONT)NUE                                                           OUTPUT.183
      )F)K .EQ. O .AND. L .EQ. OI WR)TE)6,504)                           OUTPUT.184
      WRITE)6,103) NTYPE,NEL,IS                                          OUTPUT.185
      OO 305 I=1,9                                                       OUTPUT.186
      )I=IS())                                                           OUTPUT.187
      )F()) .LE. O) GO TO 305                                            OUTPUT.188
      JJ=99)NEL-1)+II                                                    OUTPUT.189
      L=L+1                                                              OUTPUT.190
      KO(1,L)=NTYPE                                                      OUTPUT.191
      KO(2,L)=NEL                                                        OUTPUT.192
      KO(3,L)=II                                                         OUTPUT.193
      KO(4,L)=JJ                                                         OUTPUT.194
      ISTR(II,NEL)=1                                                     OUTPUT.195
      IF)L .LT. 8) GO TO 305                                             OUTPUT.196
      WRITE)20) KO,L                                                     OUTPUT.197
      K=K+I                                                              OUTPUT.198
      L=0                                                                OUTPUT.199
  305 CONTINUE                                                           OUTPUT.200
      GO TO 2000                                                         OUTPUT.201
  406 CONTINUE                                                           OUTPUT.202
      NSS=K                                                              OUTPUT.203
C                                                                        OUTPUT.204
C     REAO ANO PRINT WALL FORCE OUTPUT SPECIFICATION                     OUTPUT.205
      L=0                                                                OUTPUT.206
      K=0                                                                OUTPUT.207
      READ 1,KK3                                                         OUTPUT.208
 3000 CONTINUE                                                           OUTPUT.209
      READ 1,NW,IW                                                       OUTPUT.210
      IF)NW .GT. O) GO TO 407                                            OUTPUT.211
      IF(L .EQ. O) GO TO 408                                             OUTPUT.212
      WRITE)40) KO,L                                                     OUTPUT.213
      K=K+1                                                              OUTPUT.214
      GO TO 408                                                          OUTPUT.215
  407 CONTINUE                                                           OUTPUT.216
      IF)K .EQ. O .ANO. L.EQ. O) WRITE(6,505)                            OUTPUT.217
      WR)TE)6,104) NW,IW                                                 OUTPUT.218
      OO 306 )=I,3                                                       OUTPUT.219
      )I=)W())                                                           OUTPUT.220
      )F)))( .EQ. O) GO TO 306                                           OUTPUT.221
      JJ=3*)NW-1)+)                                                      OUTPUT.222
      )WALL)I(,NW)=1                                                     OUTPUT.223
      L=L+I                                                              OUTPUT.224
      KO)I,L)=NW                                                         OUTPUT.225
      KO)2,L)=))                                                         OUTPUT.226
      KO)3,L)=JJ                                                         OUTPUT.227
      KO(4,L)=0                                                          OUTPUT.228
      IF)L .LT. 6I GO TO 306                                             OUTPUT.229
      WR(TE(40) KO,L                                                     OUTPUT.230
      K=K+I                                                              OUTPUT.231
      L=0                                                                OUTPUT.232
  306 CONTINUE                                                           OUTPUT.233
      GO TO 3000                                                         OUTPUT.234
  408 CONTINUE                                                           OUTPUT.235
      NSW=K                                                              OUTPUT.236
C     CALCULATE LOCATION )N BUFFER FOR OISPLACEMENT(ACCELERATIONI,       OUTPUT.237
C     STRESS,WALL FORCE                                                  OUTPUT.238
      MDIS=0                                                             OUTPUT.239
      NSTR=0                                                             OUTPUT.240
      MWAL=0                                                             OUTPUT.241
      OO 307 I=1,NEQ                                                     OUTPUT.242
      IF)IOIS)II .EQ. OI GO TO 307                                       OUTPUT.243
      MDIS=MDIS+1                                                        OUTPUT.244
      IOIS(II=MDIS                                                       OUTPUT.245
  307 CONTINUE                                                           OUTPUT.246
C                                                                        OUTPUT.247
      OO 308 N=1,NUMEL                                                   OUTPUT.248
      OO 308 I=1,9                                                       OUTPUT.249
      IF()STR)I,N) .EQ. O) GO TO 308                                     OUTPUT.250
      NSTR=NSTR+I                                                        OUTPUT.251
      )STR)I,NI=NSTR                                                     OUTPUT.252
  308 CONTINUE                                                           OUTPUT.253
      OO 309 N=1.NTW                                                     OUTPUT.254
      OO 309 )=1,3                                                       OUTPUT.255
      IF()WALL)I,N) .EQ. OI GO TO 309                                    OUTPUT.256
      MWAL=MWAL+I                                                        OUTPUT.257
      IWALL)I,N)=MWAL                                                    OUTPUT.258
  309 CONTINUE                                                           OUTPUT.259
      RETURN                                                             OUTPUT.260
    1 FORMAT(I4I5)                                                       OUTPUT.261
  101 FORMAT(I5,4X,3I4I                                                  OUTPUT.262
  103 FORMAT(2I4,5X,12I3I                                                OUTPUT.263
  104 FORMAT)4X,I4,6X,3I4I                                               OUTPUT.264
  501 FORMAT(*1OISPLSECMENT ANO ACCELERATION COMPOENTS FOR*/             OUTPUT.265
     1       * WHICH OUTPUT TIME NISTORY IS REQUIREO     *//             OUTPUT.266
     2       * NOOE    O)SPLACEMENT)ACCELERATIONI COMPOENTS*/I          OUTPUT.267
  502 FORMAT))5,4X,I4,4X,*FIXEO DOF...NO OUTPUT*I                        OUTPUT.268
  503 FORMAT(* OUTPUT TYPE=1 PRINT, =2 PKINT + PLOT*,*.....*,I2/I        OUTPUT.269
  504 FORMAT(*1ELEMENT STRESS COMPOENTS FOR WHICN*/                      OUTPUT.270
     I       * OUTPUT TIME NISTORY IS REQUIREO    *//                   OUTPUT.271
     2       * ELEMENT       STRESS COMPOENTS(1,8I,YIELO(9I*/           OUTPUT.272
     3       * TYPE  NO.*/I                                             OUTPUT.273
  505 FORMAT(*IWALL FORCES FOR WHICN OUTPUT*,                            OUTPUT.274
     I       * TIME NISTORY IS REQUIREO    */                          OUTPUT.275
     2       * WALL NO.      COMPOENTS(1-FX,2-YBAR,3-FYI*/I             OUTPUT.276
      ENO                                                                OUTPUT.277
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      SUBROUTINE REPACK(IID,IDIS,ISTR,IWALL,X,X2,XH,X2H,HSIG,STH,HWALL,    OUTPUT.278
     1                  WFH,NOS,NEQ,NDIS,NOISB,NUMEL,MSTR,NSTRB,NTW,      OUTPUT.279
     2                  HWAL,NWFB,NBD,NBS,NBW,NUMNP)                      OUTPUT.280
C                                                                          OUTPUT.281
C     ******************************************************************OUTPUT.282
C     PACK RESPONSE TIME HISTORY IN OPTIMAL AVAILABLE STORAGE BLOCKS     OUTPUT.283
C     ******************************************************************OUTPUT.284
C                                                                          OUTPUT.285
      DIMENSION X(NEQ),X2(NEQ),XH(MDIS,NOISB),K2H(MDIS,NDISB),          OUTPUT.286
     1          HSIG(9,NUMEL),ISTR(9,NUMEL),STH(MSTR,NSTRB,NTW),HWALL(3,NTW)OUTPUT.287
     2          ,IWALL(3,NTW),WFH(MWAL,NWFB)                             OUTPUT.288
      DIMENSION IID(3,NUMNP),IOIS(NEQ)                                   OUTPUT.289
      REWIND 21                                                          OUTPUT.290
      REWIND 22                                                          OUTPUT.291
      REWIND 23                                                          OUTPUT.292
      L=0                                                                OUTPUT.293
      K=0                                                                OUTPUT.294
      DO 301 N=1,NDS                                                     OUTPUT.295
C     PACK DISPLACEMENT ARRAY-XH,ACCELERATION ARRAY-X2H FROM TAPE 21     OUTPUT.296
      READ(21) X,X2                                                      OUTPUT.297
      L=L+1                                                              OUTPUT.298
      DO 302 I=1,NEQ                                                     OUTPUT.299
      II=IOIS(I)                                                         OUTPUT.300
      IF(II) 302,302,402                                                 OUTPUT.301
  402 CONTINUE                                                           OUTPUT.302
      XH(II,L)=X(I)                                                      OUTPUT.303
      X2H(II,L)=X2(I)                                                    OUTPUT.304
  302 CONTINUE                                                           OUTPUT.305
      IF(L .LT. NDISB) GO TO 301                                         OUTPUT.306
      WRITE(11) L,XH                                                     OUTPUT.307
      WRITE(12) L,X2H                                                    OUTPUT.308
      K=K+1                                                              OUTPUT.309
      L=0                                                                OUTPUT.310
  301 CONTINUE                                                           OUTPUT.311
      IF(L) 403,403,404                                                  OUTPUT.312
  404 CONTINUE                                                           OUTPUT.313
      WRITE(11) L,XH                                                     OUTPUT.314
      WRITE(12) L,X2H                                                    OUTPUT.315
      K=K+1                                                              OUTPUT.316
  403 CONTINUE                                                           OUTPUT.317
      IF(NBD .NE. K) NBD=K                                               OUTPUT.318
C                                                                        OUTPUT.319
C      PACK STRESS-STH FROM TAPE 22                                      OUTPUT.320
      L=0                                                                OUTPUT.321
      K=0                                                                OUTPUT.322
      DO 306 M=1,NDS                                                     OUTPUT.323
      READ(22) HSIG                                                      OUTPUT.324
      L=L+1                                                              OUTPUT.325
      DO 303 N=1,NUMEL                                                   OUTPUT.326
      DO 303 I=1,9                                                       OUTPUT.327
      II=ISTR(I,N)                                                       OUTPUT.328
      IF(II) 303,303,406                                                 OUTPUT.329
  406 CONTINUE                                                           OUTPUT.330
      STH(II,L)=HSIG(I,N)                                                OUTPUT.331
  303 CONTINUE                                                           OUTPUT.332
      IF(L .LT. NSTRB) GO TO 306                                         OUTPUT.333
      WRITE(13) L,STH                                                    OUTPUT.334
      K=K+1                                                              OUTPUT.335
      L=0                                                                OUTPUT.336
  306 CONTINUE                                                           OUTPUT.337
      IF(L) 407,407,408                                                  OUTPUT.338
  408 CONTINUE                                                           OUTPUT.339
      WRITE(13) L,STH                                                    OUTPUT.340
      K=K+1                                                              OUTPUT.341
  407 IF(NBS .NE. K) NBS=K                                               OUTPUT.342
C     CASE OF NO WALL                                                    OUTPUT.343
      IF(NTW .EQ. 0) GO TO 412                                           OUTPUT.344
C                                                                        OUTPUT.345
C     PACK WALL FORCE ARRAY-WFH FROM TAPE 23                             OUTPUT.346
      L=0                                                                OUTPUT.347
      K=0                                                                OUTPUT.348
      DO 304 M=1,NOS                                                     OUTPUT.349
      READ(23) HWALL                                                     OUTPUT.350
      L=L+1                                                              OUTPUT.351
      DO 305 N=1,NTW                                                     OUTPUT.352
      DO 305 I=1,3                                                       OUTPUT.353
      II=IWALL(I,N)                                                      OUTPUT.354
      IF(II) 305,305,409                                                 OUTPUT.355
  409 CONTINUE                                                           OUTPUT.356
      WFH(II,L)=HWALL(I,N)                                               OUTPUT.357
  305 CONTINUE                                                           OUTPUT.358
      IF(L.LT. NWFB) GO TO 304                                           OUTPUT.359
      WRITE(14) L,WFH                                                    OUTPUT.360
      K=K+1                                                              OUTPUT.361
      L=0                                                                OUTPUT.362
  304 CONTINUE                                                           OUTPUT.363
      IF(L) 410,410,411                                                  OUTPUT.364
  411 WRITE(14) L,WFH                                                    OUTPUT.365
      K=K+1                                                              OUTPUT.366
  410 IF(NBW .NE. K) NBW=K                                               OUTPUT.367
  412 CONTINUE                                                           OUTPUT.368
      RETURN                                                             OUTPUT.369
      END                                                                OUTPUT.370
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      SUBROUTINE OUTHIS(IID,IOIS,ISTR,IWALL,TA,K,UH,NUMNP,NUMEL,NTW,     OUTPUT.3T1
     1                  NDS,NOI,NDJ,NOB,NHB,KKK,KKI,IT,JT,MT,IFF,NEQ)    OUTPUT.3T2
C                                                                        OUTPUT.3T3
C     ******************************************************************OUTPUT.3T4
C     OUTPUT RESPONSE TIME HISTORY ON SPECIFIED DISPLAY MEDIUM           OUTPUT.3T5
C     ******************************************************************OUTPUT.376
C                                                                        OUTPUT.377
      DIMENSION TMI(8I,KMI(8I,IDI3,NUMNP),ISTR(9,NUMEL),IWALL(3,NTW),TA(IIOUTPUT.378
     1          ,X(8,NDS),UHI(NOI,NDJ,I,IOIS(NEQ)                        OUTPUT.379
      DIMENSION KDI4,8I                                                  OUTPUT.380
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                           OUTPUT.381
      COMMON/EQ/DURANA,DDT                                               OUTPUT.382
C                                                                        OUTPUT.383
C     TAPE IT INPUT TAPE STORE KDI4,8I,L                                 OUTPUT.384
C     TAPE JT INPUT TAPE STORE XHI(NDIS,NDISB),K2HI(NDIS,NDISB)          OUTPUT.385
C                              STH(MSTR,NSTR8),WFH(MWAL,NWF8)            OUTPUT.386
      IF(NOB .EQ. 0) RETURN                                              OUTPUT.387
      DO 301 M=1,NOB                                                     OUTPUT.388
      IFF=IFF+1                                                          OUTPUT.389
      REWIND JT                                                          OUTPUT.390
      READ(IIT) KD,I                                                     OUTPUT.391
      DO 302 I=I,8                                                       OUTPUT.392
      TM(I)=0.0                                                          OUTPUT.393
      XM(I)=0.0                                                          OUTPUT.394
  302 CONTINUE                                                           OUTPUT.395
C                                                                        OUTPUT.396
C     PRINT APPROPRIATE TITLE                                            OUTPUT.397
C                                                                        OUTPUT.398
      GO TO (401,402,403,404) KKK                                        OUTPUT.399
  401 CONTINUE                                                           OUTPUT.400
      WRITE(6,501) M,IFF                                                 OUTPUT.401
      WRITE(6,101) (KO(I,II,KO(2,II,I=1,L)                               OUTPUT.402
      GO TO 405                                                          OUTPUT.403
  402 CONTINUE                                                           OUTPUT.404
      WRITE(6,502) M,IFF                                                 OUTPUT.405
      WRITE(6,1D1) (KO(I,II,KO(2,II,I=1,L)                               OUTPUT.406
      GO TO 405                                                          OUTPUT.407
  403 CONTINUE                                                           OUTPUT.408
      WRITE(6,503) M,IFF                                                 OUTPUT.409
      WRITE(6,1D2) (KO(I,II,KO(2,II,KD(3,II,I=I,L)                       OUTPUT.410
      GO TO 405                                                          OUTPUT.411
  404 CONTINUE                                                           OUTPUT.412
      WRITE(6,504) M,IFF                                                 OUTPUT.413
      WRITE(6,103) (KD(I,I),KD(2,II,I=1,L)                               OUTPUT.414
C                                                                        OUTPUT.415
C     ARRANGE TIME HISTORY IN OUTPUT FORM                                OUTPUT.416
  405 CONTINUE                                                           OUTPUT.417
      TT=-DDT                                                            OUTPUT.418
      N=0                                                                OUTPUT.419
      DO 3D3 N8=1,NH8                                                    OUTPUT.420
      READ(JT) K,UH                                                      OUTPUT.421
      DO 3D4 J=1,K                                                       OUTPUT.422
      N=N+I                                                              OUTPUT.423
      TT=TT+DDT                                                          OUTPUT.424
      DO 3D5 I=1,L                                                       OUTPUT.425
      GO TO (411,412,413,414) KKK                                        OUTPUT.426
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  411 CONTINUE                                                          OUTPUT.427
      JJ=KO(3,I)                                                        OUTPUT.428
      II=IOIS(JJ)                                                       OUTPUT.429
      XX=UH(II,J)                                                       OUTPUT.430
      GO TO 415                                                         OUTPUT.431
  412 CONTINUE                                                          OUTPUT.432
      JJ=KO(3,I)                                                        OUTPUT.433
      II=IOIS(JJ)                                                       OUTPUT.434
      XX=UH(II,J)                                                       OUTPUT.435
      GO TO 415                                                         OUTPUT.436
  413 CONTINUE                                                          OUTPUT.437
      LL=KO(2,I)                                                        OUTPUT.438
      II=KO(3,I)                                                        OUTPUT.439
      II=ISTRIII,LL)                                                    OUTPUT.440
      XX=UH(II,J)                                                       OUTPUT.441
      GO TO 415                                                         OUTPUT.442
  414 CONTINUE                                                          OUTPUT.443
      LL=KO(1,I)                                                        OUTPUT.444
      II=KO(2,I)                                                        OUTPUT.445
      II=IWALIII,LL)                                                    OUTPUT.446
      XX=UH(II,J)                                                       OUTPUT.447
C     ABSOLUTE MAX                                                      OUTPUT.448
  415 CONTINUE                                                          OUTPUT.449
      AX=ABSIXX)                                                        OUTPUT.450
      IF(AX-XMII)) 416,416,417                                          OUTPUT.451
  417 CONTINUE                                                          OUTPUT.452
      XMII)=AX                                                          OUTPUT.453
      TM(I)=TT                                                          OUTPUT.454
  416 CONTINUE                                                          OUTPUT.455
      XII,M)=XX                                                         OUTPUT.456
      TAIM)=TT                                                          OUTPUT.457
  305 CONTINUE                                                          OUTPUT.458
  304 CONTINUE                                                          OUTPUT.459
  303 CONTINUE                                                          OUTPUT.460
C                                                                       OUTPUT.461
      GO TO (418,419) KKI                                               OUTPUT.462
  418 CONTINUE                                                          OUTPUT.463
      00 306 N=1,MOS                                                    OUTPUT.464
      WRITE(6,104) TA(N),(X(I,M),I=1,L)                                 OUTPUT.465
  306 CONTINUE                                                          OUTPUT.466
      WRITE(6,105) (XMII),I=1,L)                                        OUTPUT.467
      WRITEI6,106) ITMII),I=1,L)                                        OUTPUT.468
      GO TO 420                                                         OUTPUT.469
  419 CONTINUE                                                          OUTPUT.470
      IF(KKI .EQ. 2) WRITEINT) IFF,KKK,L,KD,XM,X                        OUTPUT.471
      GO TO 418                                                         OUTPUT.472
  420 CONTINUE                                                          OUTPUT.473
  301 CONTINUE                                                          OUTPUT.474
      RETURN                                                            OUTPUT.475
  101 FORMATI8H    TIME,2X,8(I8,1H-,I2,X))                              OUTPUT.476
  102 FORMATI8H    TIME,2X,8II4,2H--,I3,1H-,I2))                        OUTPUT.477
  103 FORMAT(8H    TIME,2X,8(I8,1H-,I2,X))                              OUTPUT.478
  104 FORMATIF8.3,2X,8E12.4)                                            OUTPUT.479
  105 FORMATI* MAXIMUM ABSOLUTE VALUES*/,* MAXIMUM  *,8E12.4)           OUTPUT.480
  106 FORMATI* MAXMUM VALUE TIME*,F10.5)                                OUTPUT.481
  501 FORMATI*1TIME HISTORY FOR SELECTED DISPLACEMENT COMPOENTS*,       OUTPUT.482
     I       5H.....I3,3TX,*FILE NO.*,I3//                            OUTPUT.483
     2       20X,*NODE NUMBERS AND DISPLACEMENT COMPOENTS*)            OUTPUT.484
  502 FORMATI*1TIME HISTORY FOR SELECTED ACCELERATION COMPOENTS*,       OUTPUT.485
     1       5H.....I3,3TX,*FILE NO.*,I3//                            OUTPUT.486
     2       20X,*NODE NUMBERS AND ACCELERATION COMPOENTS*)            OUTPUT.487
  503 FORMATI*1TIME HISTORY FOR SELECTED STRESS COMPONENTS*,            OUTPUT.488
     1       5H.....I3,41X,*FILE NO.*,I3//                            OUTPUT.489
     2       20X,*ELEMENT TYPE-ELEMENT NO.-STRESS(1,8),YIELO(9)*/)    OUTPUT.490
  504 FORMATI*1TIME HISTORY FOR SELECTED WALL FORCE*,                   OUTPUT.491
     1       5H.....I3,4TX,*FILE NO.*,I3//                            OUTPUT.492
     2       20X,*WALL NO.-COMPOENTS,1=X,2=YBAR,3=Y*/)                OUTPUT.493
      END                                                               OUTPUT.494
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